INDUSTRIAL WASTE DIVERSION PROGRAM

THE DEVELOPMENT OF A CANADIAN ENVIRONMENTAL PROTECTION TECHNOLOGY TO REMOVE AND RECOVER CFCs FROM DISCHARGE GAS STREAMS

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THE DEVELOPMENT OF A CANADIAN ENVIRONMENTAL PROTECTION TECHNOLOGY TO REMOVE AND RECOVER CFCs FROM DISCHARGE GAS STREAMS

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Technology to Remove & Recover CFCs
For: Ontario Ministry of the Environment

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EXECUTIVE SUMMARY

This report details the results of a project undertaken by ORTECH International for the Linde Division of Union Carbide Canada to develop a technology for the capture and recycling of Chlorofluorocarbons (CFCs).

This project is Phase I of a planned multi-phase development program aimed at establishing a commercial venture to capture and recycle CFCs.

The Linde technology is based on adsorption of CFCs on to a proprietary organophilic, hydrophobic molecular sieve with subsequent recovery of the captured CFCs.

The four major objectives of this phase of the project were:

(1) To prove the technical effectiveness of the Linde approach through laboratory experimentation

(2) To compare this technology with alternative capture and recycling technologies

(3) To investigate which applications of the technology make sense, from a practical and economic point of view

(4) To recommend to government what actions should be taken to ensure that CFCs are controlled.

The results of the laboratory program, detailed in Section 4 of this report showed that the technology was effective in capturing all CFCs, HCFC 22 and for those experimental substitute HCFCs and HFCs, of which we were able to obtain samples.

The balance of the objectives were met by a combination of literature review, interviews and plant visits. It was concluded that there are a number of CFC emission sources to which the technology could be applied, the most promising of which for immediate follow-up are:

- Sterilant gases
- Household refrigerators and air conditioners
- Degreasing solvents

Details of these reviews are included in Sections 2, 3 and 5.

It was concluded that quite strong government action would be required to ensure that CFC capture and recycling were undertaken. These needs are discussed in detail in Section 6.

1. BACKGROUND AND INTRODUCTION

Chlorofluorocarbons are a family of long-chained halogenated organic chemicals used widely in both the industrial and service sectors. They were introduced in the 1930s as industrial refrigerants and, as more was learned of their unique properties, were employed in a wide variety of applications. Almost 20,000 tonnes of CFCs were used in Canada in 1987.

CFCs are extremely stable chemicals, so, when released to the atmosphere, they are very long lived. Eventually, these compounds rise to the ozone layer in the upper atmosphere, where intense ultraviolet radiation breaks the molecule, releasing chlorine atoms which, in turn, react with the ozone in a chain reaction destroying many thousands of ozone molecules. Reduction in ozone concentration results in less ultraviolet radiation being absorbed. The additional U.V. radiation reaching the earth has the potential to increase the incidence of skin cancer, cataract formation and immune system suppression.

Recognition of the seriousness of the threat to the ozone layer came at an international conference held in Montreal in September of 1987. At this meeting, an agreement was signed by 24 countries, including Canada, to reduce CFC emissions by 50% by 1999. This agreement is now widely referred to as the Montreal Protocol.

The response to the Montreal Protocol has been extremely responsible. Many governments around the world have initiated with even more stringent requirements than those set out in the Protocol. This is illustrated in Figure 1.1(1) for Canada, Norway, Sweden and Germany. It is interesting to note that some local governments (e.g. City of Toronto (2) in Canada, and City of Irvine in California(3)) have established local approaches to controlling CFCs.

Large industrial users of CFCs have also responded with strategies to phase out their own use of CFCs on timetables which are more aggressive than that set out at the Montreal meeting.

In February, 1989(4), the Ontario Government tabled a proposed amendment to the Ontario Environmental Protection Act which had a suggested timetable as follows:

July 1, 1989:	CFC aerosols and rigid foam packing made with CFC prohibited
December 31, 1989:	A system to be in place to collect and recycle CFCs from air conditioners and portable insulated coolers
July 1, 1990:	Use of rigid foam insulation and furniture foam made with CFCs to be prohibited. Halon gases must be captured and recycled when fire extinguishers are taken out of service
December 31, 1991:	CFCs banned as solvents
December 31, 1992:	Halons may no longer be vented during fire extinguisher tests
July 1, 1994:	CFC recycling ends and these compounds must be recaptured and destroyed
July 1, 1998:	The use of CFCs in refrigerators, air conditioners and coolers prohibited

This was an extremely aggressive proposal and somewhat unrealistic in terms of timing. A 1990 news release(5) from the Ministry of the Environment calls for the following:

- Phase out by 1993 the use of CFCs in producing rigid foam insulation and flexible foam in furniture
- Ban, as of July 1, 1990, of CFCs in aerosols and home repair kits for refrigerators and automobile air conditioners
- Remove the exemption for CFCs as aerosol propellants for certain drugs and medicines and for insulation foam as of July 1, 1990
- Require capture and recycle of CFCs during servicing of automobile air conditioners

CFCs are extremely useful chemicals providing cooling, solvent cleaning, foaming of plastics for insulation or for comfort in furniture, as carriers in medical operations, and for fire protection. Their attractiveness in all of these applications, in addition to their effectiveness in that they are non-toxic to humans, have no terrestrial adverse environmental effects and are non-flammable. Until their negative effect on the ozone layer was recognized, they were regarded as extremely "environmentally friendly" substances.

If one accepts the premise that, what CFCs were being used to accomplish, was, and is needed, and that we would like to continue to have refrigerators, air conditioners, foamed insulation, etc., then we need to consider what our alternatives may be. There are three approaches one can take to alleviate the negative effects of CFCs:

1. Find substitute chemicals with similar properties to CFCs, but which do not harm the ozone layer
2. Find a different way of doing things, e.g. elimination of solvent degreasing
3. Ensure that there is no release of CFCs to the atmosphere

Substitutes

It should be recognized that not all organic chemicals containing halogen atoms are equally harmful to the ozone layer. A measure of Ozone Depleting Potential (ODP) has been established, which relates chemicals to CFC 11 as an ozone depleting potential of 1.0. The ODP(6,7) for the CFCs and Halons covered in the Montreal Protocol are as follows:

	ODP
CFC 11	1.0
CFC 12	1.0
CFC 113	0.8
CFC 114	0.8
CFC 115	0.4
CFC 500	<1.0
CFC 502	<0.4
Halon 1211	3.0
Halon 1301	10.0
Halon 2402	6.0

All of the CFCs and Halon 1301 have low toxicity for humans. Halon 1211 and 2402 are used in situations to minimize human exposure. All of the CFCs are non-flammable or very resistant to thermal degradation.

So the challenge facing the developers of substitutes for the CFCs and Halons are as follows:

(a) Duplicate the primary properties of the CFC as closely as possible
(b) Develop a substance with an ODP of 0 or close to 0
(c) Develop a substance which is non-toxic to humans

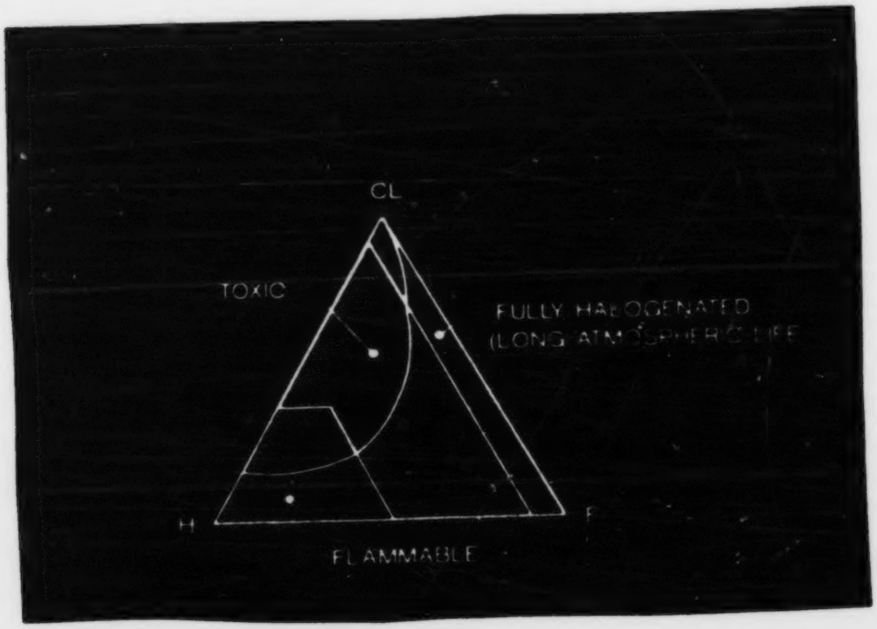
(d) Develop a substance which is non-flammable

(e) Develop a substance which has no adverse effect on the lower atmosphere or water or plant or animal life.

This is a difficult challenge. For CFCs, the majority of effort is going into non-fully halogenated organics that minimize the amount of chlorine in the molecule. These HCFCs (hydro, chloro, fluoro carbons) or HFCs (hydrofluorocarbons) have much lower ODPs than the fully halogenated substances. Some of the substitutes in use or being developed are as follows:

	ODP
HCFC 22	0.05
HCFC 1415	0.1
HCFC 123	0.02
HFC 134/134a	0
HFC 152a	0

A paper by McLinden[8] summarized the challenge faced to developers of substitutes in a simple diagram:



In general, fully halogenated compounds tend to have long atmospheric life. Increasing chlorine content tends to lead to physiological toxicity and increasing hydrogen content tends to lead to increasing flammability.

HCFC 22 is currently being used extensively in air conditioning units for the home and in some commercial air conditioning. A number of other HCFCs and HFCs are being rigorously tested for toxicity, flammability, etc.

The list of alternatives being considered for current CFCs is shown in Table 1.1(6).

There is generally agreement that the cost of the substitutes will be substantially higher than the current cost of refrigerants. This will occur for a number of reasons:

- The cost of developing and testing new substances is substantially higher now than when the original refrigerants were developed
- Production facilities will be capitalized in 1990s" dollars rather than 1940s', 50s' and 60s' dollars
- In a number of cases, the actual production is more complex requiring a number of steps to arrive at the final product.

Because of the higher costs of the substitutes, there may be substantial interest in controlling emissions of these substances for economic rather than environmental reasons.

Operational Changes

Much of the effort in trying to eliminate emissions of CFC 113 is going into alternative operating methods. As can be seen from Table 1.1, there are no proposed HCFC or HFC substitutes for CFC 113.

CFC 113 is used extensively for solvent degreasing in the electronics industry to clean circuit boards. Approaches being investigated include the use of aqueous degreasing systems and the use of no-flux soldering systems to eliminate the need for degreasing.

Control Release of CFCs to the upper atmosphere

As an interim measure and, indeed, as a long term measure to control substitutes, an attractive and practical option is to control the release of CFCs to the upper atmosphere.

Refrigerants are used in equipment that typically has a relatively long life. With manufacture of CFCs being phased out, CFC needed to service this equipment will have to come from captured and recycled refrigerant from equipment going out of service.

For Halons and CFC 113, there are no substitutes on the horizon, so, if use cannot be eliminated, control of emissions may be the only approach.

CFCs are used in medical applications because of their properties of low toxicity and flammability. The substitutes may not be able to match this performance, so continued use of CFCs in medical applications may be desirable. Capture and recycle would make that an acceptable practice.

There are basically two approaches to controlling emissions of CFC:

- Condensation/compression
- Adsorption

Many different systems have been or are being proposed, but all rely on one of these two approaches.

Condensation/compression is most appropriate for use in servicing of larger cooling equipment, where it is necessary to remove CFC from the system prior to work being carried out. In some instances, the removed CFC can be reintroduced following the repairs being made. For equipment going out of service, the condensation/compression approach is also appropriate to consider.

For any instances when the CFC is diluted in any amount by air or other gases, condensation/compression will not work. Here, an adsorption approach, followed by regeneration, is most appropriate. For small scale cooling equipment, e.g. household refrigerators, freezers and air conditioners, as will be discussed in Section 5, the adsorption approach may have some practical advantages. Examples of CFC emissions more appropriately controlled by adsorption are:

- From solvent degreasing
- From flexible foam manufacture
- From rigid foam manufacture
- Leaks from refrigeration equipment
- Control of Halons emitted during use for fire control
- Control of sterilant gases in hospitals

The Linde Division of Union Carbide Canada Ltd. has undertaken this project to establish the efficacy of using a proprietary organophilic, hydrophobic molecular sieve to capture CFCs from air streams. This material is completely inert and is quite selective for compounds such as the various CFCs of interest. While it is very successful at adsorbing these types of compounds, it is also very easy to remove the compounds from the sieve under very mild conditions, with no degradation of the captured material.

As was discussed in the paragraphs above on Substitutes, the HCFCs and HFCs being developed as substitutes for the fully halogenated CFCs are projected to be much more expensive. The incentive for controlling these substitutes may be more economic than environmental. The molecular sieve is also quite effective at capturing these compounds. Even after the eventual phase out of the CFCs required under the Montreal Protocol, capture and recycling technologies will have a role to play.

There were four main parts to the project which are described in this report. The four parts and the chapters in which they are covered were:

1. Review of Alternative Capture and Recycling Technologies (Section 3)
2. Prove the Technical Effectiveness of the Linde Approach through Laboratory Experimentation (Section 4)
3. Investigate What Applications of the Technology Make Sense from a Practical and Economic Point of View (Sections 2 and 5)
4. Recommend to Government What Actions They Would Need to Take to Ensure that CFCs Are Controlled (Section 6).

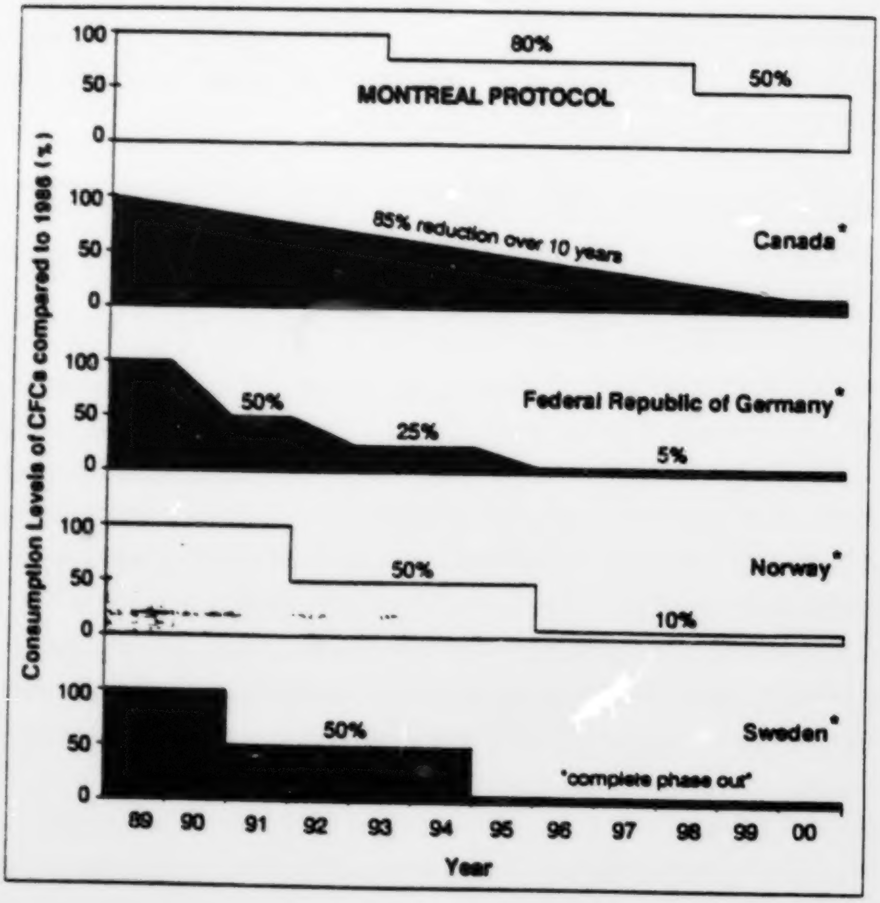
TABLE 1.1 - LIST OF ALTERNATIVES(6)

CFC REFRIGERANTS					CFC ALTERNATIVES				
NAME	FORMULA	NBP (°C)	ODP [a]	GP [b]	NAME	FORMULA	NBP (°C)	ODP [a]	GP [b]
R113	$CFCl_2CF_2Cl$	48	0.8	0.3 - 0.8					
R11	CCl_3F	24	1.0	0.32	R141b	CCl_2FCH_3	32	0.1	0.05
					R123/123a	$C_2HCl_2F_3$	27	0.02	0.1
R114	$CClF_2CClF_2$	4	0.8	0.5 - 1.5	R143	CHF_2CH_2F	5	0	—
					C318	$CF_2CF_2CF_2CF_2$	-6	0	—
					R142b	$CClF_2CH_3$	-9	0.06	< 0.2
					R124	$CHClFCF_3$	-12	0.02	< 0.1
					R134	CHF_2CHF_2	-20	0	< 0.1
R12	CCl_2F_2	-30	1.0	1.0	R152a	CHF_2CH_3	-25	0	< 0.1
R500	CCl_2F_2/CHF_2CH_3	-33	< 1.0	< 1.0	R134a	CF_3CH_2F	-27	0	< 0.1
					R218	$CF_3CF_2CF_3$	-37	0	—
R115	$CClF_2CF_3$	-38	0.4	1 - 3	R22	$CHClF_2$	-41	0.05	0.07
R502	$CHClF_2/CClF_2CF_3$	-45	< 0.4	1 - 3	R143a	CF_3CH_3	-48	0	< 0.3
					R125	CF_3CHF_2	-48	0	< 0.2
					R32	CH_2F_2	-52	0	—
					R23	CHF_3	-82	0	—

a. OZONE DEPLETION POTENTIAL RELATIVE TO R11 = 1.0,
DATA FROM UNEP MEETING, THE HAGUE, 17-18 OCTOBER 1988

b. GREENHOUSE POTENTIAL RELATIVE TO R12 = 1.0,
DATA FROM DuPONT, FLUOROCARBON/OZONE UPDATE, MARCH 1987

FIGURE 1.1 - Proposed CFC Consumption Reduction Plans Compared to the Montreal Protocol



2. CFC USE IN CANADA

2.1 General Information on Manufacturing, Distribution and Use of CFCs in Canada

CFCs are manufactured, distributed and utilized by various companies across Canada. Data reflecting the use of CFC by industry sector has been gathered by Environment Canada for the past few years and is presented in Table 2.1. Information on who the major CFC stakeholders are in Canada is presented in Tables 2.2 (manufacturers), 2.3 (importers) and 2.4 (major buyers of CFCs in Canada).

As can be seen from both Tables 2.1 and 2.4, the major use of CFCs in Canada occurs with the manufacture of plastic components - flexible and rigid foams, while the use of CFCs in the refrigeration and air conditioning sectors comes in second. In Ontario, 70% of the large volume purchasers of CFC are in the plastics industry. In order to control CFC discharges, it is important to understand who handles and uses CFCs in each industry sector. Information on how CFC is handled in each industry sector is given in Section 2.5. CFC use in the plastic industry can be easily monitored and potentially controlled due to the limited number of use areas. However, the Refrigeration and Air Conditioning industry can be much more complex to monitor and potentially regulate due to the numerous individuals and businesses who can come in contact with CFC and CFC containing equipment.

Various stakeholders have interest in the CFC issues in Canada. They range from government bodies, non-government organizations (NGOs) to industry and trade associations. A description of the CFC issues as it affects these stakeholders and the applicability of the UC Blue Bottle™ technology will be evaluated in the following sections.

2.2 Government Agencies

2.2.1 Environment Canada

Aside from the Montreal Protocol, other national efforts to assist in the implementation of programs to phase out CFCs is occurring on an ongoing basis. The Commercial Chemicals Branch at Environment Canada has compiled information on CFC use in industry for the past several years. This information has been instrumental in developing Canadian Use Patterns for both CFCs and Halons(9). The industry sectors have been divided according to the CFC application, and further subdivided as appropriate in the separate categories (see Table 2.1). These quantity data have been used to help establish the need for specific programs and efforts in which Environment Canada has become involved and which are described in the following sections.

Documentation on Technical Options for Preserving The Ozone Layer

Environment Canada has been very involved with the United Nations Environment Program (UNEP) reporting on technical options to reduce CFC use. Mr. Vic Buxton from Environment Canada has been the Panel Chairman for a series of six reports describing the various options available to specific industry sectors worldwide in order to comply with the CFC reduction deadlines(7,19-22). A separate Report, outlining Canada's options to meet CFC reduction objectives in the various industry sectors has also been completed(18). These options, whether they are substitutes, revisions of processes to reduce or eliminate CFC consumption or recycling and recovery options, will be discussed further in Section 2.5

Draft Code of Practice(11)

Environment Canada, along with the Heating, Refrigeration and Air Conditioning Institute (HRAI) and various industries have developed a Draft Code of Practice for refrigeration and air conditioning manufacturing service, repair and decommissioning. This Code is based on a similar document published by the Commission of European Communities. As a Code of Practice, it has no authority as law, but its use can be encouraged by the trade and industry associations, as well as by those individuals or organizations that conduct business with them.

The main purpose of this proposed Code is the reduction of CFC emissions into the atmosphere by the three general areas of: (1) commercial; (2) domestic refrigeration and air conditioning; and (3) mobile air conditioning. The report deals with the mechanics of each system type and how various components could be made more conducive to CFC reductions. The various components of the code are:

1. design of systems
2. manufacturing procedures
3. installation and servicing of units
4. advice to system users
5. recovery, reuse and disposal of refrigerants
6. handling and storage of refrigerants
7. disposal of equipment containing CFCs
8. training of personnel

Upon review of the document, we submitted recommended revisions to the Draft Code of Practice which would allow the use of adsorbent technology like the Blue Bottle™ to be used as a recovery technology. Prior to this recommendation, only Vampire technologies were considered to be appropriate for CFC capture and recovery.

Environment Canada has assured us that this recommended change will be included in the finalized version(17). This Draft Code of Practice has not yet been released to the public.

Purity Standards for Recycled CFCs

Purity Standards for recycled CFC need to be established to encourage the reuse of recovered CFC where it has been sufficiently purified. The Society of Automotive Engineers (SAE) in the United States have established purity values from CFC recovered from automobile air conditioners. They have also issued documents that detail the recovery procedure and equipment to be used to reach these purity limits(26,27). In Canada, the Canadian Standards Association (CSA) has been contacted by Environment Canada to establish purity codes for reclaimed refrigerants. These purity standards will probably be developed in conjunction with the refrigeration industry and based on the standards issued by the Air Conditioning and Refrigeration Institute in the U.S.(23).

Training Programs

Environment Canada has been assisting various trade associations, such as HRAI, in the development of training programs to help member industries and businesses undertake CFC reduction programs. This training program includes the development of instruction manuals, participation manuals, and a video. Preliminary training programs have just started in Toronto in August and should be finalized by the end of the month(23).

2.2.2 Provincial Initiatives

Each of the Provinces and Territories have either initiated regulations with respect to CFC reduction strategies or are considering their options. Environment Canada has been working with representatives from each province and territory via an ad hoc task force on CFC issues. This is an attempt to coordinate an approach throughout Canada regarding CFC use restrictions and is a mechanism to keep all provinces informed of the most recent developments on CFC issues. The City of Toronto and a representative of the Canadian Federation of Municipalities is also represented and the legal role and responsibility of the municipality to deal with CFC use restrictions is also being evaluated. Tables 2.5 and 2.6 give a summary of contacts from this ad hoc CFC task force and their positions on CFC issues in their jurisdictions. Only Ontario, Manitoba and Environment Canada have released their timetables for CFC reductions.

Manitoba has included in their regulations mandatory recycling and recovery of CFC from both commercial (1991) and domestic refrigeration (1992), units(24), while Ontario stipulates CFC capture from service and maintenance from auto and other mobile air conditions units in July, 1991. Recycling and recovery initiatives in commercial and domestic refrigeration will likely be announced shortly in Ontario(5).

2.2.3 Municipal and Regional Government Initiatives

Many municipalities are starting to evaluate their roles in CFC emission reduction strategies, but none so far-reaching in Canada as that proposed by the City of Toronto in the "Chlorofluorocarbon Reduction Strategy for Toronto"(2). The City of Toronto has proposed the following steps to be taken:

(1) Enact a municipal by-law governing the control of CFCs and halons as designated by the Montreal Protocol

(2) A prohibition in sale, manufacture and use of CFC based packaging

(3) A prohibition in the manufacture, sale and use of CFC based aerosols

(4) A prohibition in the manufacture, sale and use of CFC based insulation

(5) Mandatory reclamation of drainable CFCs prior to product disposal

(6) Mandatory CFC audits and waste minimization plans for CFC-using establishments

(7) Mandatory minimum standards for refrigerant servicing (i.e. as that proposed by HRAI)

(8) Enforcement of a by-law to control CFCs

(9) Government boycott of CFC based products

(10) Promotion of the development and implementation of CFC recovery and disposal technologies

(11) Promotion of citizen action to minimize CFC emissions

Other large municipalities, like Vancouver, Montreal(13) and Ottawa(14) are also engaging in CFC reduction strategies, while several smaller municipalities (Guelph, Hamilton, Waterloo) have begun to evaluate their best courses of action. The The Federation of Canadian Municipalities is not overseeing any major group effort in this respect, but feels that the large municipalities do have good CFC reduction policies. Specific initiatives by municipalities which could impact the use of the Blue Bottle™ are the recycling and recovery strategies that may be imposed. Municipalities are generally responsible for white goods collection and disposal and many are evaluating recycling and recovery strategies for CFCs from these particular appliances. Pilot studies will be under way in Toronto and Montreal shortly. These initiatives will be discussed under the Domestic Refrigeration Industry Sector.

TABLE 2.1 - Canadian Use Pattern for CFCs and Halons (1987)[9]

Use Sector	Subsector Use	Quantity tonnes/yr	Category %	Total %
Plastic Foam	Rigid insulation	5,704.0	62.0	
	Rigid packaging	1,804.0	20.0	
	Flexible foam (furniture)	828.0	9.0	
	Flexible foam (automobile)	644.0	7.0	
	Foam (other)	184.0	2.0	44.0
Total		**9,200.0**	**100.0**	
Refrigerants & Air Conditioning	Commercial Refn/A/C (installation & service)	3,604.0	53.0	
	Mobile A/C new units (export)	1,156.0	17.0	
	Mobile A/C new units (domestic)	952.0	14.0	
	Mobile A/C (service)	816.0	12.0	
	Domestic Refn (new units)	204.0	3.0	
	Domestic Refn (service)	68.0	1.0	33.0
Total		**6,800.0**	**100.0**	
Aerosol	Slurrying agent	1329.8	61.0	
	Propellant	632.2	29.0	
	Other	174.4	8.0	
	Solvent	43.6	2	11.0
Total		**2,180.0**	**100.0**	

Contd.

Table 2.1 (contd.)

Use Sector	Subsector Use	Quantity tonnes/yr	Category %	Total %
Solvents	Electronic	1,501.0	79.0	
	Metal cleaning	380.0	20.0	
	Drycleaning	19.0	1.0	9.0
Total		**1,900.0**	**100.0**	
Miscellaneous	Sterilization	532.0	76.0	
	Others	112.0	18.0	
	Testing gas	21.0	6.0	3.0
Total		**700.0**	**100.0**	

TABLE 2.2 - Manufacture of CFCs in Canada(10)*

Company	Production Capacity (tonnes/yr)	Actual Production (tonnes/yr)
Allied Chemical, Canada Amhurstberg, Ontario	15,000	N.A.
DuPont Canada Maitland, Ontario	18,000	N.A.
Total	33,000	21,000

*NOTE: Halons are not manufactured in Canada

N.A.: Not available

TABLE 2.3 - CFC Importers(10)

Distributors	Quantity (tonnes/yr)
Allied Chemical Canada, Mississauga, Ontario	N.A.
CIL, Willowdale, Ontario	N.A.
DuPont Canada, Montreal, P.Q.	N.A.
Total	1,800

N.A.: Not available

TABLE 2.4 - Major Buyers of CFCs in Canada(2)

Company	Location	End Use
Ontario:		
Arconas	Mississauga	Flexible urethanes
BASF	Toronto	Rigid and flexible urethane systems
CIL Industries	Toronto	Aerosols
C-I-L	Mississauga	Rigid urethane systems
Camco	Weston	Refrigerants
ER Carpenter	Toronto	Flexible urethanes
Delaney & Pratt	Ajax	Flexible urethanes
Domfoam	Bramalea	Flexible urethanes
Donlee Plastics	Weston	Flexible urethanes
Dow Chemical	Mississauga	Polystyrene bead
Franklin Manufacturing	Cambridge	Refrigerants
General Refrigeration	Downsview	Freezers, coolers
General Latex & Chemicals	Brampton	Rigid urethane systems
Hoover Chemical	Tilsonburg	Flexible urethanes
Iroquois Chemicals	Cornwall	Rigid & flexible systems
Mitel Corp.	Kanata	Solvent
Polyrim	Thornhill	RIM components
Reeves Bros.	Toronto	Flexible urethanes
3M Canada	London	Solvent
Vitafoam Products	Toronto	Flexible urethanes
Witco Canada	Oakville	Rigid urethane systems
Wood, W. C.	Guelph	Freezers
Woodbridge Foam	Woodbridge	Flexible urethanes

Contd.

TABLE 2.4 (contd.)

Company	Location	End Use
Other Canadian Provinces:		
A-Z Sponge & Foam Products	B.C.	Flexible urethanes
Anatek Electronics	B.C.	Solvent
Canadian Marconi	Quebec	Solvent
Coldstream Products of Canada	Manitoba	Refrigerants
Carpenter Jackson	Alberta	Flexible urethanes
Domfoam	Quebec	Flexible urethanes
Hupp Canada	Quebec	Refrigerants
Les Industries PPD	Quebec	RIM Components
Miller Foam Enterprises	Quebec	Flexible urethanes
Perma Frost Refrigeration	Quebec	Refrigerants
Sussex Refrigeration Mgf	N.B.	Refrigerants
Vitafoam Midwest	Alberta	Flexible urethanes
Waterville Cellular Products	Quebec	Semi-rigid urethanes

TABLE 2.5 - CFC Regulations and Phase Outs by the Federal Government and Each of the Province

Province	1990	1991	1992	1993
Ontario	As of July 1, 1990, use of CFCs in slurries used in aerosol preparations will be banned. Ban home repair kits for domestic refrigerator & auto A/C. Remove exemptions for CFCs as aerosol propellants for certain drugs, medicines & for insulation foam.	As of July 1, 1991, require capture & recycle of CFCs during maintenance & service of auto A/C & truck & railcar refrigeration units (government anticipates mandatory commercial & institutional A/C & refrigerant systems capture & recycle during servicing).		Ban CFC use in rigid foam insulation & flexible foam used in furniture.
Manitoba	The following will be banned: • Packaging, wrapping & containers made with ozone depleting substances • Aerosol propellants with ozone-depleting substances except prescription drugs • One kg CFC canisters used to recharge auto A/C • Domestic halon fire extinguishers • Portable pressurized canisters of CFCs used as solvent or release agent	CFCs in commercial sized A/C & refrigeration must be recovered & recycled. Certification & procedure requirements for servicemen developing for 1991. Halon based fire extinguishers need permits.	CFCs in smaller sized A/C & refrigeration units must be recovered & recycled.	Solvents, flexible furniture foam & rigid foam insulation made with CFCs will be banned. Further restrictions on CFCs in refrigeration equipment & halons in fire extinguishers.

TABLE 2.5 (Contd).

Federal Government	1989	1990	1992	1993	1998	1999
Presently undergoing revisions(23)	Freeze in consumption of CFCs (July 1)	Ban import, manufacture & sale of aerosol products with CFC (exempt certain medical products & essential fire safety products) (January 1) Ban import, manufacture & sale of food packaging foam, including food, beverage, containers containing or manufactured with controlled CFCs (January 1) Ban import, manufacture & sale of portable halon fire extinguishers for homes (January 1) Ban import, manufacture & sale of small pressurized canisters that contain controlled CFCs, including refrigerants, air horns and party streamers (January 1)	Freeze in consumption of halons (January 1)	20% reduction of CFC consumption (July 1)	50% reduction of CFC consumption (July 1)	85% reduction of CFC consumption (new estimates are 100% elimination by 1997)(23)

TABLE 2.5 (Contd)

FEDERAL PROJECTED PROHIBITION DATES FOR VARIOUS CFC USE CATEGORIES

Use Category	% Canadian Use (1987)	Product Group	Projected Prohibition
Aerosol	9	All	End of 1989 except medical & essential safety products
Rigid Foams	33	(a) Insulating foams	
		- polyurethane	1992-1994
		- polystyrene	1990-1991
		- phenolic	1991-1992
		(b) Packaging	
		- food	1990
		- other	1990-1991
Flexible Foams	8	Car seals Furniture cushions, etc.	1990-1992
Refrigeration	36	(a) New refrigeration & air conditioning	1994-1999
		(b) Existing equipment maintenance	As replacements are available
Solvents	10	Electronic	1991-1994
		Metal cleaning	1990-1991
		Drycleaning	1991-1992
Others	4	Hospital Sterilants Optical coatings	1990-1994

TABLE 2.6 - Other Provinces/Territories Initiatives

Quebec:	Discussion of CFC legislation has been delayed by concern of CFC classification as hazardous wastes. Options include making solvent and CFC blowing use as creating hazardous wastes, but have other uses excluded. Also concerned with having regulations similar to Ontario to ease inter-provincial transportation
New Brunswick:	No regulations yet; are waiting for Environment Canada to develop approach. Have no major users except refrigeration
Prince Edward Island:	No regulations yet; are waiting for Environment Canada. No manufacturers, just service
Nova Scotia:	Legislation that is being prepared is intended to control the manufacture, sale and use of specific products made with CFCs. Will ban halon extinguishers, small cans. Would like to set up transport industry demonstration. No major users, just service industry. Not their intention to enforce recovery of CFCs at this time. Recovery/recycling will be addressed in a code of practice for CFC/halon usage. Would be happy to help promote recovery and recycling projects
Newfoundland:	No regulations yet; waiting for Environment Cana

Table 2.6 (contd.)

Saskatchewan:	Draft regulations near completion
British Columbia:	Draft regulation being prepared under Waste Management Act. Waiting for Executive support for regulations. Have no manufacturers; have some foam blowers but no inventory of who and what quantities. Can discourage use of CFC and halons. Vancouver is developing by-laws
Alberta:	No draft regulations yet, but interest is there. Have some large users of CFC, particularly in foam and insulation areas.
Yukon:	Are in the developing stage for draft regulations, introducing new regulations in new legislature. No manufacture use of CFC, but use in refrigeration. Have workshops on developing legislation.
N.W.T.	No regulations. No large manufacturer use. Use in air conditioning and refrigeration.

2.3 Non Government Organizations (NGOs)

Various environmental groups have issued statements in support of CFC reduction timetables. Friends of the Earth (FOE), however, has been the most vocal and active group promoting CFC reductions on both a national and global effort through its various sister organizations around the world. FOE has issued recommendations to Environment Canada on CFC reduction strategies(25) which include complete elimination of CFC use by 1995. Even with total CFC elimination, the Blue Bottle™ concept can still be applicable to the CFC substitutes in areas such as refrigeration and foam blowing.

2.4 CFC Release Per Industry Sector

This section describes how CFCs are used in the various industry sectors. Plant visits were conducted to better understand how CFCs are subsequently emitted to the environment. The following industry sectors were evaluated:

(1) Commercial refrigeration/air conditioning
(2) Domestic refrigeration
(3) Mobile air conditioning
(4) Foam products manufacturing (rigid and flexible foams)
(5) Solvents
(6) Fire extinguisher systems (portable and total flooding)
(7) Sterilant gases
(8) Aerosols

Flow diagrams were created to depict CFC use and areas of potential leak and/or recovery prospects. Information in each sector is presented in the following format, where appropriate:

(1) review of control options
(2) use of CFCs in equipment manufacture
(3) CFCs from leaks
(4) CFCs from service
(5) CFCs from scrap or decommissioning

Discussions were also held with trade and industry associations representing specific industry sectors. Details of plant visits and meetings are given in Appendices 1-6.

2.4.1 Commercial Refrigeration and Air Conditioning

The primary CFCs used in commercial refrigeration and air conditioning are CFC 11, 12 and 115 (as part of an azeotropic blend R502 which is a 51/49 mix of CFC 115 and HCFC 22 - see Table 2.7). Environment Canada reports that the most likely control options include use of alternative refrigerants in new units as the industry shifts to suitable compressors and modified equipment such as with high pressure centrifugal chillers using HCFC 22. Alternatives, such as HCFC 22, can also be used for leak testing, both at the manufacturing and at the job sites. Recycling and recovery of CFCs used in servicing could be better promoted, particularly if education and training are stepped up in this area and manufacturers design units to allow safe and controlled removal of CFC, i.e. installation of isolation valves to facilitate the process. One other stumbling block exists, and that is the recognition of quality standards for recovered CFCs(11). The use of CFCs in this industry sector is presented as a flow diagram in Figure 2.1 and discussed in the following sections

Equipment Manufacture

Manufacturers of commercial size refrigeration/air conditioning equipment has used CFCs for leak detection of new equipment. This is carried out on line in the assembly process. Many manufacturers have phased out use of CFCs altogether and use inert gases such as He or have replaced testing mixtures with dilute streams (i.e. 5%) of CFC with an inert stream such as N_2. The trend appears to be going away from use of CFCs for this practice.

Leaks

Equipment is often installed by service agents recommended by the manufacturer. Installation can also be done, however, by any number of independent agents who may not have proper training in the handling of CFCs. Thus, installation may be an area to control leaks by proper education.

Leaks occurring at the site of equipment use appears to be a major source of CFC discharge. Old equipment is particularly prone to leaks and owners are reluctant to call in servicemen until necessary. Major revamping of equipment is expensive and would probably not be considered until either regulations promote use of good functioning equipment (i.e. by penalizing owners of leaky equipment) or by economics whereby the purchase of new CFCs on a regular basis becomes very costly.

To control leaks on a regular basis, a U.K. company, Stanley Refrigeration Limited, has launched a new preventive maintenance service which aims at reducing the discharge of CFCs to the atmosphere from retail refrigeration systems. The program called SPACE (Stanley Protects and Conserves the Environment) will involve regular store visits by refrigeration engineers (i.e. certified to handle leaks) to test for leaks and carry out inspections. The frequency of these visits will depend on the amount of refrigeration equipment within the store, but most will receive a weekly visit at no extra charge. Stanley reports that a system can leak for up to 1 month before it is detected, and, by detecting small leaks quickly, major problems can be averted, saving the customer money and down time(31).

Leaks may be difficult to capture once they occur because they could happen anywhere in a system such as in cooling coils, compressors or tubing. It may be suitable, in some cases, to enclose a compressor room area, for example, to exhaust out through a mol sieve bed which could have a leak detection system placed with it.

Some industries and commercial institutions have already purchased the Vampire type CFC recovery units for use on site. This allows the pump-down of CFC from chillers or freezers as required and direct reintroduction of the compressed CFC. As these commercial size units can be quite large, there can be a significant cost saving in the purchase of new CFCs.

Service

Servicing of large chillers and coolers can result in CFC emissions from venting of the gas prior to service, using CFC to clean out system prior to recharge, and CFC escape from purge valves and lines. CFCs are also known to be vented during the use of recycling/reclamation equipment when this equipment needs to be emptied in order to change over for use with other CFCs. Many of the CFC issues relating to the service aspect are covered in the Draft Code of Practice(11). Some servicemen are already recovering CFCs prior to service, using the commercially available Vampire units that are reviewed in Section 3. Capture and recovery of CFCs in the commercial refrigeration service area appear to be well under way from both industry and government initiatives, using widely available technologies that are capable of handling large volumes of CFCs.

Scrap or Decommissioning

Companies or businesses who own equipment destined for replacement are starting to become more concerned with the implications of various disposal aspects. Several large operations in the hotel business have already started to specify in their replacement contracts for room air conditioners that the refrigerant from the units to be replaced be removed and recovered and not vented. Companies who offer this as a service can claim that they are more environmentally friendly by complying with the proposed Code of Practice for scrap decommissioning. Some businesses are going even further and dismantling the products to segregate recyclable components such as copper tubing, plastic and metals. One particular company who manufactures room air conditioning units is also anxious to use recovered refrigerants (HCFC 22) in their units as a selling point to their customers.

2.4.2 Domestic Refrigerators, Freezers and Air Conditioners

The domestic refrigeration and freezer markets rely almost exclusively on the use of CFC 12. Air conditioning and heat pumps use HCFC 22 and data have not been collected by Environment Canada yet in this area (see Table 2.8). The same service industry, however, would likely service both sets of appliances and, therefore, preliminary information is included here on air conditioning units.

The control options, as foreseen by Environment Canada, is the use of substitute materials, i.e. HFC 134a in the longer term and, possibly, ammonia which would require significant redesign of units. Isolation valves could be added to facilitate recovery. While recovery units seemed to be more widely available for the commercial refrigeration area, because of the larger quantities involved, fewer suitable options exist for the domestic refrigeration market. In this service sector, shorter service calls are required and the servicemen are not willing to carry large, bulky pumps into customer homes. The federal government also suggests that recycling efforts, such as with discarded appliances, would be best addressed at the provincial or municipal levels(11).

A flow diagram showing the complex network of business involvement in the domestic refrigeration handling area is shown in Figure 2.2 Although the individual unit quantities are quite small compared to the commercial sector, the large numbers of refrigerators involved yields a high quantity of banked CFC. Table 2.9 is an attempt to survey selected municipalities to try to establish quantities of CFC recoverable from scrap recycling initiatives.

Equipment Manufacture

CFCs have been used in equipment manufacture for leak detection in the domestic refrigeration area, but many are replacing this test with He. An industry average of 0.03% of manufactured units fail at the testing line and need to be dismantled and the gas recovered. Many manufacturers already have their own recovery equipment and, because the material that is withdrawn is very pure, it can be taken out and reintroduced directly back into a system. A Vampire type of unit has been used successfully by many manufacturers.

Leaks

As with the commercial refrigeration area, in use leaks do occur, but would be difficult to capture unless a silicalite bed could be established surrounding all potential leak areas, i.e. coils, tubing, etc.

Service

It has been estimated that less than 10% of refrigerators and freezers ever need servicing(19). An even lower estimate is given by AHAM of 2% of units during warranty periods (up to 5 years) and 1% thereafter In Canada, an estimated 68 tonnes was used in service in 1987. Public pressure for environmentally friendly refrigeration service has resulted in the service industry's interest in recovery technologies.

The service industry would have an increased role to play in the capture and recovery of CFCs during repair of units. The service industry requires that any system used for recovery be simple and easy to use, light weight and easily portable into a household, yet visible to the homeowner as a CFC recycling apparatus. The system discharge must be made quickly and not require significant quantities of accompanying equipment to take in.

Most systems available to date weigh in excess of 100 lbs before recovered refrigerant is added. Many machines are also unable to extract all refrigerant from sealed systems, some leaving as much as 10%. The available systems are also costly, starting at recovery-only machines for $2,000 (US). Systems that claim to purify used refrigerants may not provide clean enough material for direct reintroduction. CFC 12 from refrigerators is more difficult to purify than that from automobile air conditioners where the chief contaminants are moisture and air. The other contaminants found in refrigerators include acids and oil by-products from compressor motors, which are harder to extract. Servicemen who reintroduce material directly to systems may not be able to judge accurately the quality of the used refrigerant and may be held liable for product damage(36). Appliance manufacturers are skeptical about the capabilities of portable recycling systems and many are concentrating on providing servicers with recovery only ability.

To date, the only system available on the market in North America to recover CFCs from residential sector refrigerants is the Inglis bag system. This system appears to work well, can take 3 refrigerators' discharges into the system, is portable and expandable. Criticisms of the system exist and these include the unwieldy size once fully expanded and the potential for leaks in the plastic bag itself. The system is only a capture system and, therefore, would require further processing for repurification, leaving the refrigerator repairshop with bags of captured CFCs.

The service industry association, CEASA, has been very enthusiastic about the Blue Bottle™ concept and its membership was given a demonstration by Linde/ORTECH at one of their meetings. This demonstration was well received. CEASA was particularly impressed with the portability and versatility of the process. As there is only a single gas, CFC 12, used in this sector, there would be less chance to cross contaminate the bottle contents with other CFCs.

Scrap Decommissioning

The repair and reuse industry could also be interested in a 'Blue Bottle' device, since, as in the service area, portability is a highly desirable criterion. The repair and scrap businesses are generally not occurring in a home environment but rather at a shop where larger Vampire type units are also appropriate. The scrap metal industry, in itself, is not particularly interested in carrying out CFC recovery, although the end users, the scrap reprocessors, have expressed interest in making sure that their scrap has been properly decommissioned.

The scrap metal industry, through ISRI (Institute of Scrap Recycling Industries) has been quite vocal in the past by advising members not to accept white goods in the fear that they may contain PCB containing capacitors. In the CFC issues, ISRI is encouraging manufacturers to "Design for Recycling", so that CFCs can also be easily recovered. Recovery of CFC from insulating foams at this time may not be economically/technically feasible according to ISRI. Some companies in the U.S. have built their business by assuring sources of scrap goods that have capacitors removed and CFCs drained from all refrigerators and freezers. Appliance Recycling Centers of America (ARCA) is the largest U.S. appliance recycler who picks up and decommissions the units for recycling, while about 10% are reconditioned for resale(34). They recycle numerous other components of the white goods as well, such as copper, plastic, aluminum and other metals. In the U.S., the Global Environmental Protection Bill, which had been introduced into Congress, would require the removal of CFCs from every freon bearing object before recycling, making scrap decommissions a more attractive prospect(36). A flow diagram showing CFC 11 emissions from the domestic refrigerator/freezer network and the possible recovery/emission areas is given in Figure 2.3.

In the U.K., refrigerator recycling stations are being developed to recycle all CFCs from domestic appliances by the end of 1992. The Bird Group, a metals recycling specialist based in the English Midlands, Imperial Chemical Industries (one of the main producers of CFCs in Europe) and Lindemann Maschinenfabrick of West Germany have created a partnership to create the first complete recycling station. They hope to recycle the CFC from the refrigerant as well as in the insulating foam.

The foam will be compressed and the gas it contains extracted. CFCs will be separated out and purified through a complex cooling and condensation process before being sent for refinement and eventual reuse where possible. This technology could also be extended to recycling other products, such as insulating foams used in the building industry. Metal parts would be sent for recycling as usual. They hope to set up similar plants around the world(41).

The quantity of CFC 12 left in scrap refrigerator/freezer units is still not known, but some reports from the Netherlands and AHAM indicate 80% of refrigerators picked up for recovery still had significant quantities of CFC in them.

Some municipalities are interested in undertaking pilot studies to recover CFC from scrapped white goods because scrap pick-up falls under their jurisdiction. The City of Toronto, in particular, is proposing to undertake a pilot study using equipment developed in the Netherlands. This equipment incorporates a liquid transfer system and has processed over 40,000 scrapped refrigerators via a fixed or mobile unit. Other municipalities have employed not-for-profit groups to recover scrap white goods such as in the Region of Ottawa Carlton. A charitable organization, Recycle Appliance, picks up scrapped white goods, repairs and resells the useful ones and recycles various components of the unusable ones - including the CFC. At the present time, the CFC is recovered via a homemade liquid transfer system and is accumulating at the site because nobody is interested in taking it. Other Regions, such as Waterloo, are investigating the range of CFC recovery units available and will be making a decision to either contract this service out or to do it themselves at their recovery facility.

2.4.3 Mobile Air Conditioning

Mobile air conditioning systems primarily use CFC 12. Cars with air conditioning systems in Canada comprise an average 30-40% - a figure which the industry predicts will steadily grow over the next few years. Auto manufacturers are generally going to wait to change over their equipment until the prospective replacement HFC 134a is approved. Some manufacturers, i.e. Volvo in Sweden, have announced a changeover in the interim to HCFC 22, although this changeover is not generally expected by the industry(33). Some States in the U.S. have taken a regulatory approach and have banned cars in their State which utilize CFC 12 in their air conditioning systems.

The flow diagram in Figure 2.4 shows the expected leak areas of CFC 12 and Table 2.10 presents the facts relating to this industry sector.

Manufacture

Some loss of CFC will occur at the manufacturing level from filling of new air conditioners, although Environment Canada expects this loss to be low enough not to warrant control equipment(18). Some manufacturers report, however, that there may be some interest in capturing fugitive emissions from the filling area as well as from the storage areas for CFC in the plant. High costs are expected for HFC 134a which may make recovery more attractive.

Leakage

Some reports indicate that 30% of CFC is lost every 5 years in cars with minimal leakage(31). Individual automobile owners will no longer be able to purchase 1 lb cans of CFC 12 for their own air conditioning units because they are prohibited from sale by the new provincial regulations. Capture from leak areas is difficult because of the high volume and cost of mol sieve required compared to space allocations in a car.

Service

Car air conditioning repair facilities will be regulated as of July 1, 1991, to capture CFC on regular servicing. Many large automakers are making sure their dealerships comply with these orders and are supplying them with recovery units. G.M. has supplied their dealers with Robinair units and Chrysler is testing another PCU CFC recovery unit at their facilities. Some dealers still would prefer not to have to train their personnel in the use of these units and would welcome a simple bleed off system that could be captured in an adsorbent and transferred to a recovery facility.

Reuse of CFC recovered during air conditioning service will be eligible for reintroduction immediately if the following specifications are met and the recommended procedures are followed as per SAE proposed standards(26,27):

(1) moisture - 15 ppm by weight
(2) lubricant - 4,000 ppm by weight of mineral oil based lubricant
(3) non-condensible gas - 0.15 grams of non-condensible gas per lb of refrigerant.

The refrigeration reclamation equipment must be approved by the Underwriters Laboratories or an equivalent certifying laboratory.

In general, the CFC obtained from car air conditioning will be relatively clean and could be reintroduced back into the system with few expected problems.

Scrap

Environment Canada expects that a sizable portion of CFC could be obtained from cars prior to wrecking. It is unknown how many vehicles still contain any air conditioning charge when they are destined for the scrapyard, but the banked potential of CFC could be significant.

Although individual scrapyards contacted did not appear to be very interested in setting up a CFC recovery facility, there may be some pressure applied by their customers to have the CFCs drained and, in effect, decommission the automobiles. Another sector that may be able to capture CFCs is the dealers as they receive cars as trade-ins for new vehicles. Dealers may already own their Vampire units from air conditioning servicing and it may be of interest to them to decommission cars from their facility as well.

2.4.4 Foam Production

CFC use in the plastic foam industry can be divided into two primary categories, rigid and flexible. CFC is retained in the closed cells of the rigid foams, which provide insulating value to the materials (i.e. foam insulation, packaging trays, etc.). In flexible foam manufacturing, CFCs are used as auxiliary blowing agents, primarily as fire suppressors in the blowing process. These are released directly to the atmosphere. Flexible foam products include furniture and carpet underlays. Figure 2.5 gives a list of types and major uses of CFC blown foams.

Table 2.11 presents the subdivided foam industry and the types of CFC, their quantity consumed per sector, and the names of sample companies contacted.

Rigid Foam

In the rigid foam industry, polyurethane, polystyrene and phenolic foams' manufacturing is by far the largest consumer of CFCs. A flow diagram of CFC use patterns in this sector is shown in Figure 2.6.

Rigid Polyurethane Foams

Manufacturers

Insulating rigid foam production benefits by trapping as much CFC into the closed cells as possibly, thereby reducing emissions and increasing their R value. Most of the CFC (i.e. 90%) remains in the product(43). Adsorption technologies may be too expensive to be considered for CFC emission control, due to the small quantities released(18). Some polyurethane foam products are also produced via "foam in place", i.e. on the job site, which would make adsorption technologies even less feasible. The industry is exploring the use of some soft CFCs such as HCFC 123, 1416 as substitutes for CFC 11 and HCFC 22 or HFC 134a as substitutes for CFC 12 (used primarily for frothing).

ICI has recently been investigating the reduction of CFC blowing agents used in the production of rigid and flexible polyurethane foam and has already developed foams using 50% less CFC. Insulating materials such as those used in refrigerators and freezers are being produced with half the usual CFC quantities with minimal effect on the insulation properties. HFCs are being considered to replace CFCs in these situations.

Rigid Phenolic Foam Insulation

Phenolic foam insulation is produced in a manner similar to other rigid foams. The primary use of the CFC 11 in this process is to retain it in the closed cells to increase the R value of the board. As much as 95% of the CFC is trapped in the board, resulting in minimal emissions. Where open cell board manufacturing exists, it seems that they will be replaced by closed cell boards because of the greater insulating value(18). Alternative blowing agents such as HCFC 123 and HCFC 141b are being considered as substitutes when they become commercially available.

Rigid Polystyrene

Polystyrene boardstock production uses CFC 12 in the manufacturing process, and also attempts to trap all of the CFC in the closed cells. Therefore, emissions are again very low. The major producer of polystyrene boards in Canada has already replaced their CFC 12 with a soft HCFC 22, which Environment Canada views only as a bridging chemical(18). Other low ODP substitutes chemicals may be considered when available.

Rigid Foam Packaging

Polystyrene foam sheet products are used primarily in the food packaging industry in Canada. These companies had agreed on a voluntary basis to substitute HCFC 22 by the end of 1988, and may adopt the use of HCFC 134a as it becomes available(18). Plant emissions would again be fairly low as most of the blowing agent is trapped in the cells.

Flexible Foam

In flexible foam manufacturing, CFC 11 is used as an auxiliary blowing agent in some cases. Flexible foam manufacturing takes place both as slabstock (primarily furniture) and as moulded products (primarily automobile components). The flow diagram of CFC use patterns is given in Figure 2.7.

In slabstock manufacturing, the primary blowing agent is CO_2 which is generated by the reaction of isocyanates and water. CFC 11 is required as an auxiliary blowing agent in about 35% of the cases, i.e. high density soft foams (~ 10%) and low density foam (~ 25%). Control options for this sector include(48):

(1) the use of alternative blowing agents, i.e. methylene chloride and formic acid (both potentially dangerous to workers)

(2) increasing the water in production processes to produce more CO_2, thereby reducing the need for auxiliary blowing agents (but potentially increasing risk of fire)

(3) replacement of CFC 11 by much more expensive HCFC 123 and/or HCFC 141b (although they are not yet available and health risks by using 123 in particular may be of greater concern than for CFC 11)

(4) chemical modifications of polyols used in the process, particularly for 25% of market producing low density foams; these modifications would enable new polyols to withstand higher temperatures which would then not require CFC additions; also in the 10% of market producing soft high density foams, new modified polyols known as heteropolyols are also being developed to withstand higher temperatures. These substitutes may be available in 1993

(5) emission controls using adsorption technologies (i.e. carbon adsorption has been tested in a pilot plant in Denmark for several years(43) where sacrificial filters may be required to prevent potential polyurethane fouling. The same report describes that plants over 100 tonnes of CFC consumption per year in Sweden may be expected to more than offset their operating costs for this emission control technology

(6) emission controls by building new plants with vertical foam chamber systems; these systems would have a much smaller output by working at ≈ one-tenth the speed of horizontal lines and the collection efficiencies may not be much greater than those for horizontal chamber lines.

Union Carbide Corporation also offers a process known as Ultracel™ Foam Technology that enables flexible foam production without the use of auxiliary blowing agents. A proprietary process, Union Carbide claims it can be used with slabstock production to produce improved foam products cost effectively in an environmentally responsible manner(45).

Recently, a CFC recovery plant was installed in the U.K. at Hyman RLC Draka Foam Factory at Glossop in Derbyshire with assistance of a grant from the Department of Trade and Industry. This plant incorporates carbon adsorption(44). Other carbon regeneration units have been operating in Belgium at the Recticel plant where they have been able to regenerate 40% of the CFC 11 used with exhausted concentrations of CFC at an average of 500 mg/m^3, but still admit to only a limited theoretical understanding regarding the CFC adsorption(46).

Approximately 84% emission at the flexible foam level are released in the first 2 hours of manufacture. The extremely high air flow rates (i.e. 30,000 CFM at each fan) are needed (Appendix 5) to reduce worker exposure to the chemicals in the air. With adsorption technology such as mol sieve, the air movement may have to be modified to be better suited for the technology, yet protect the workplace environment. Many flexible foam manufacturers have already reduced their consumption of CFCs significantly by modified procedures (i.e. higher water content) and project a potential of 80% reduced CFC requirement. By 1993, CFC use in flexible foam used in furniture will be banned in Ontario, and substitute HCFCs will probably be used only where other modifications are not suitable.

CFC reduction from moulded flexible foams are much easier to accomplish by greater conversion to completely water blown systems. This is apparently suitable to the manufacturers as it produces a firmer automobile seating which is becoming more desirable now anyway. The other control options, as mentioned for slabstock, are also applicable but may not be necessary as converting to water blown systems is the easiest option(18).

Scrap Recovery

An interesting, and possibly exciting, new area to consider CFC recovery is from the trapped closed cells of insulating foam materials. Recovery of

CFC from open cells is pointless because there is virtually no CFC left in the foam. CFCs can apparently be trapped in these closed cell materials for several decades with minimal release to the atmosphere. One report suggests that even exposed foam with CFC 11 has a half-life of 100 years(12). Several industries have already indicated their intention to recover CFC from foam materials such as insulation from refrigerators and freezers, as well as building and construction insulation(41) (Appendix 2).

Separation of the foam from adhered structural components such as the walls of refrigeration units may pose some difficulty. Scrap foam recovery from polyurethane foam materials was evaluated in Sweden by crushing the polyurethane foam into fine particles and rolling to squeeze out the CFC as well as by placing the fractured particles under a vacuum to force out the CFC. Both of these attempts resulted in the release of minimal quantities of CFC, and the authors resolved that incineration of the foam was the only reasonable manner to ensure that CFCs were not slowly released into the environment for decades to come(43).

In other areas, such as West Germany, CFC is extracted. Reports from Germany suggest that the cost of CFC 11 recovery from refrigerator foam may add an additional U.S. $15 to the cost of disposal, plus another U.S. $15 for the cost of CFC 12 recovery. Similar calculations from Japan have estimated at costs of U.S. $94 for foam CFC 11 recovery which includes transportation costs(19).

It is estimated that the CFC in foam insulation contains four times as much CFC as that contained in CFC 12 as a refrigerant(19). For 1990, an estimated total of 675,000 refrigerators were manufactured in Canada (see Table 2.8), with approximately 0.2 kg of CFC 12, which corresponds to approximately 0.8 kg of CFC 11. This means approximately 540 tonnes of CFC 11 were used to manufacture the polyurethane insulation, which corresponds to about 10% of the demand for CFCs in rigid insulation (1987 values). Other sources of scrap foam from insulating materials could probably be acquired from industrial off-cuts and construction/demolition industry as municipalities are searching for alternatives to disposal of solid wastes, should recovery of CFC from foam be of interest.

2.4.5 CFCs Used in Solvents

In Canada, the use of CFC 113 as solvents accounted for 9% (1987) of the total CFC use. The greatest percentage of use is in the electronic industry degreasing sector (78% at 1,501 tonnes), followed by metal cleaning (20% at 380 tonnes) and drycleaning (1% at 19 tonnes). The use of CFC 113 in the electronics industry (see Figure 2.8) has expanded over the last number of years due to the high efficiency of the solvent to remove fluxes and resins following soldering of printed circuit boards, as well as the compatibility of 113 with certain plastic components. Control options to reduce CFC use in the electronics industry vary with the type of operation and the desired product. It has been estimated that a number of operations use CFC 113 to clean their systems, although this high degree of purity may not always be required. Some firms may only require CFC cleaning standards on a few of their products. Where a high degree of cleanliness is required, the manufacturer may have to comply with "military specifications" which have required specifically the use of CFC 113. This specification of procedure rather than purity of outcome has been a major area of discussions between industry and the U.S. Navy. To help resolve the issue of CFC 113 use in the production of military equipment, the electronics industry, government and the U.S. Navy have collaborated on a project known as "China Lake".

Other alternatives to the reduction of CFC 113 use are aqueous washing systems, use of low solid flux soldering techniques, use of terpene based cleaning systems, and, as interim measures, blending of 113 and alcohols.

Major users of 113, such as Northern Telecom, have initiated efforts to totally phase out of CFC use in the next few years, where technically possible. Conservation and recycling programs have evolved out of this corporate commitment and enabled a 40-50% reduction of CFC use.

Recycling of CFC 113 on-site or off-site has been slow to occur because of the low relative cost of 113 compared to the cost of the product(14), but off-site recyclers are quite capable of purifying materials to required specifications.

Manufacturers' Use of CFC as Solvent

CFC 113 use as a solvent can result in emissions occurring primarily in the following areas:

(1) bath evaporation
(2) solvent carry-over
(3) evaporation of waste solvent
(4) spray evaporation
(5) storage and transfer of bulk shipment

Containment of these areas where the air can be drawn through an adsorption system has been used by both Northern Telecom and IBM. Northern Telecom introduced a carbon adsorption system in Calgary which has had a payback in less than 9 months and enabled a significant reduction in purchase of CFC required for cleaning. IBM also uses a carbon adsorption system, but this system has been operating much longer and may not be as efficient as a new carbon bed. In Sweden, some electronics cleaning is carried out in enclosed equipment and activated carbon beds are said to recover 80% of CFC. Losses appear to occur from the carbon filters (5-10%) and from evaporation from equipment on weekends(43).

Alternatives for CFC used in the metal degreasing sector may be to return to the acid or alkali washing systems which also have their associated wastewater problems(18).

CFC 113 is used in small quantities in the drycleaning industry, primarily to clean suedes and leathers. Very few operations use 113, but the emissions could be better controlled by use of adsorption systems by areas of high leaks such as on the doors of the units or above bath areas. Substitutes, such as the soft HCFC 123, may also be used(21).

2.4.6 Halons in Fire Extinguishers

Halons are bromofluorocarbons that have a remarkable fire fighting capability. They are basically non-toxic in use, but have a very great ozone depleting potential. Two primary types of halon systems are in use today as fire protection equipment:

(1) the portable hand-held systems utilizing 1211
(2) the total flooding systems which utilize 1301.

Portable Fire Extinguishers

Environment Canada has banned the import, manufacture and sale of portable halon fire extinguishers as of January 1, 1990, as per their announcement in February, 1989(50). Use of dry chemicals for portable fire extinguishers have increased. A short term use of the mol sieve technology may be in the decommissioning of portable halon equipment as it is taken out of use. This could occur in conjunction with household hazardous collection facilities in various municipalities. See flow diagram in Figure 2.9 for potential emission scenarios.

Total Flooding Systems

In Canada, the large majority of halons used in fire protection are actually banked in equipment. This gives rise to an opportunity to install halon capture technology such as mol sieve in conjunction with these systems.

In the event of a fire alarm triggering halon release, the halon saturated environment could be exhausted through a mol sieve bed. Most fire alarms are triggered under fairly sensitive conditions and, therefore, smoke contamination, although a potential problem, may be minimal. Another area of potential proprietary molecular sieve use is with the dismantling and decommissioning of these systems as companies decide to employ alternative fire protection equipment. Alternatives, such as water, carbon dioxide, dry chemicals, and water and foam mixtures (Aqueous Film Forming Foam, or AFFF) are presently being evaluated by many companies(7).

The use of halons in fire protection equipment may be found to be the best possible protection method in a number of different cases where use of other systems pose additional risks. Areas where halons could be continued to be used include National Art Galleries and Museums, and centralized telecommunication areas. The UNEP report on halons(7) advises that proper training of installation contractors and licensing of halon users could help control the inadvertant release of halons to the environment. Figure 2.10 illustrates potential halon emission scenarios.

2.4.7 CFCs in Sterilization Gases

Sterilization of medical equipment/devices can be done in a number of ways, including steam, irradiation, dry heat, formaldehyde and an ethylene oxide [Eto] (12% by weight) and CFC 12 (88%) mixture, known as "12/88". Where heat sensitive materials need to be sterilized, the 12/88 mixture seems to be the method of choice, particularly in hospitals. In many cases, substitute processes may be possible and there are currently available cryogenic systems to recycle the 12/88 mixture and reuse it. Alternatively, HCFC substitutes for CFC 12 are also being tested for compatibility both with Eto and with the numerous types of products it is required for sterilizing(22). A recent report indicated that Allied Signal Inc. has developed an environmentally acceptable fluorocarbon to replace CFC 12 in its blend with ethylene oxide Eto. It has the sterilizing capability providing the same margin of safety as the product currently under use, can directly replace CFC 12 in equipment with no retrofitting and can sterilize successfully using substantially less Eto. This last benefit could further reduce worker exposure(49).

Reports of recovery systems for sterilant CFC 12 have helped reduce consumption in Sweden. Although purchasing rates for CFC 12 halved, the company had difficulty in disposing of the recovered CFC because it could not be reused for sterilization(43).

Recovery systems for CFC 12 or its substitute materials may be especially attractive to Linde who markets the sterilant gas to hospitals. Figure 2.11 illustrates possible CFC losses in sterilant use.

2.4.8 CFCs Used in Aerosols

The use of CFCs in aerosols was the largest sector of CFC use in the world in 1986. A significant reduction of CFC use in aerosols has already begun. Ontario has banned use of CFCs in slurry preparations for aerosols and as propellants as of July 1, 1990. Therefore, no ongoing requirement for CFC capture and recycling will occur. However, there may be some potential for the short term to establish aerosol product dismantling facilities and capture of released CFCs. ShredTech is a company who specializes in developing shredding technologies, and has been contacted by interested parties about the shredding of aerosol cans. This shredding component could be carried out in an enclosed container, such that the released gases could be trapped on a mol sieve bed. ShredTech has expressed interest in using this combination of shredding and adsorption technology to process aerosol containers and recover the CFCs. Figure 2.12 gives a flow diagram showing potential CFC losses and recovery points.

TABLE 2.7 - Commercial Refrigeration & Air Conditioning

	CFC Sector Use Commercial Refrigeration & Air Conditioning			
	Centralized Air Conditioners (i.e. Hospitals/office buildings/ schools)	Retail Refrigeration Cases and Freezers	Commercial & Industrial Chillers	Total
Primary Type of CFC Used	12	12, 22, 115	11, 12	
Quantity of CFC Used in Canada (1987) tonnes/yr				3,604 (not including HCFC 22)
Quantity of CFC per unit (weight)	Ave. several hundred lbs	Ave. 800 lbs	Up to 3 tonnes	Several kgs to 1 tonne
Average Lifetime of Units				20-25 years
Estimated Quantity of Units in Canada				10,000,000
Sample Companies/Industrial Associations Contacted				
Manufacturers	Carrier, Copeland/HRAI, ASHRAE	Hussman	Keeprite	
Leaks	HRAI		Schneiders	
Service	Power Watch Industries, Accutherm, Carrier, U.S. Navy/HRAI (includes all 3 ref. areas)			
Scrap	Intermetco, Power Watch Industries, Environmental Applications Group/CARI, ISRI (includes all 3 ref. areas)			

TABLE 2.8 - Domestic Refrigeration

CFC Use Sector Domestic Refrig. and A/C	Primary Types of CFC	CFC 12 Used/ Available in Canada (tonnes/yr)	Quantity of CFC per Unit (weight)	Average Lifetime of Unit (Industry Estimate)	Estimated Manufacture/ Sale in Canada (1990)	Sample Companies Contacted	Industry Associations Contacted
Manufacture		204 (Env. Can. 1987				W. C. Woods Inglis WCI	CAMA EMAC AHAM
Refrigerators	12			17 years	675,000		
Old (1970s & earlier)			285 g				
New (1980s +)			213 g				
Freezers	12			21 years	235,000		
Old			426 g				
New			285 g				
A/C Room (small window size)	22		440 g	15 years	90,000		
A/C Central	22		2.3-3 kg				

contd.

Table 2.8 (contd.)

Domestic Refrig. and A/C	Quantity of CFC Used by Service Sector (Env. Can. 1987) (tonnes)	# Refrigerators Requiring CFC Removal for Servicing/year	Quantity of CFC Recoverable Estimate (max. calculated)	Sample Companies Contacted	Industry Associations Contacted
Service	68 (refrigerators and freezers)	40,000-80,000 (from CEASA servicing estimates)	10-20 tonnes/yr (refrigerators and freezers from CEASA estimates) or 4-5 tonnes/year (from AHAM estimates)	Inglis Sears WCI	CEASA AHAM
Refrigerators/Freezers					
Leaks			Industry estimates of 20% units are empty when servicemen arrive	Inglis Sears WCI	CEASA AHAM

Domestic Refrig. and A/C	Calculated Quantity of CFC Available from All Units Scrapped at End of Their Average Lifetime (1990 tonnes/yr)	Sample Companies Contacted	Industry Associations Contacted
Scrap			
Refrigerators	192	Various municipalities Intermetco Ottawa Recycle Appliance Store Environmental Applications Group	ISRI
Freezers	76 or ≈ 100 T/yr total (from AHAM estimates)		

TABLE 2.9 - Municipally Scrapped Refrigerators, Freezers and Air Conditioners

	Estimated Numbers						
	Refrigerators	Freezers	Air Conditioners	Total White Goods	Population Served	Scrap Dealers	Considering By-Laws
Cambridge				100 tons/yr			
East York	1000/yr		125/yr	2500 items/yr		Intermetco	
Guelph				2600 items/yr			Evaluating CFC recovery options for city
Halton				No records on quantities		I.W.S. Ferrous	
Hamilton				Under study		Tricil sells as scrap	Evaluating CFC recovery options for Region
Lindsay				225 tons/year		Newcastle Salvage Co.	
Montreal							Considering by-law for CFC recovery & recycling. Setting up pilot for scrap recovery
Ottawa	30/wk winter 100 /wk summer	4-5/wk		7-10,000 items/year	7-800,000	Recycle Appliance Store (collection & repair) Baker Met (scrap dealer)	Considering: Purchasing policies in city Recommended enact & enforce by-law for CFC emission controls Have scrap pick-up & CFC recovery

Contd.

TABLE 2.9 (contd.)

	Estimated Numbers						
	Refrigerators	Freezers	Air Conditioners	Total White Goods	Population Served	Scrap Dealers	Considering By-Laws
City of Toronto	100/wk	1-2/wk				Intermetco	Considering by-law for CFC recovery & recycling. Setting up pilot for scrap recovery
Tosorontio Twp				10 appliances/ week	1,100	Inland Metals	
Vancouver				Under study			Considering by-law similar to Toronto
Waterloo				850 tons/yr			Evaluating CFC recovery options for Region
Windsor				315 tons/year (4700 items)	60,000	Zalev Bros.	

TABLE 2.10 - MOBILE A/C

CFC Use Sector	Primary Type of CFC	Quantity of CFC Used in Canada (Env. Can. 1987) Tonnes/yr	Quantity Per Car	Average Lifetime	Estimated # Units (1990)	Sample Companies Contacted (Manufacture, Leak Service)	Industry Association Contacted
Mobile A/C	12	1156 (new units export) 952 (new units domestic) 816 (service)	2 kg (old) 1.4 kg (new) (1985)	30%of CFC lost 15 yrs due to leakage (Ref. 25)	1.2 million cars/yr & A/C (30-40% of new cars have A/C) = 1,064,000 kg banked	Chrysler Can. Ford Canada	Motor Vehicle Mfgs. Association
						(Scrap) Intermetco Stelco	ISRI

TABLE 2.11 - Plastic Foam Production

CFC Use Sector	Primary Type of CFC Used	Quantity of CFC Used in Canada (1987) Tonnes/yr	CFC Emission Control Applicable	Total Annual Canadian Consumption	Sample Companies Contacted	Trade Association Contacted
Rigid Polystyrene Foam Packaging	12 and HCFC 22 as replacement	1840	No		(Manufacturing)	
					--	--
Rigid Polyurethane & Polystyrene	11, 12, 113	5704	No	Polyurethane foam - 33,000 tonnes	Dow Inglis W. C. Woods	CAMA
					(Scrap)	
					Environ. Applications Group	ISRI
Flexible Foam (furniture)	11	828	Yes		(Manufacturing)	
					Curon Can.	CFFMA
					(Scrap)	
					N/A	N/A

Table 2.11 (contd.)

CFC Use Sector	Primary Type of CFC Used	Quantity of CFC Used in Canada (1987) Tonnes/yr	CFC Emission Control Applicable	Total Annual Canadian Consumption	Sample Companies Contacted	Trade Association Contacted
Flexible Foam (automobile)	11	644	Yes (but greater movement to water blown systems)		(Manufacturing)	
					--	--
					(Scrap)	
					N/A	N/A
Foam (other)		184			(Manufacturing)	
					--	--
					(Scrap)	
					N/A	N/A

TABLE 2.12 - CFCs Used in Solvent

CFC Use Sector	Primary Type of CFC Used	Quantity of CFC Used in Canada (1987) Tonnes/yr	Quantity of CFC Used per Unit	Sample Companies Contacted Manufacturers	Industry Association Contacted
Electronic	CFC 113	1,501	200kg CFC/ 100 m^2 board (industry average)	Northern Telecom; Litton; IBM	
Metal Degreasing	CFC 113	380			
Drycleaning	CFC 113	19			

TABLE 2.13 - Halon Usage and Emissions

HCFC Used Sector	Primary Type of Halon	Quantity of Halon Used in Canada (1987) tonnes/yr	Sample Companies Contacted
Portable Fire Extinguishers	1,211	460 (total)	Northern Telecom Gary Taylor
Banked in equipment		368	
Controllable emissions		46	
Fires		46	
Total Flooding Systems	1,301	310 (total)	Northern Telecom Gary Taylor
Banked in equipment		217	
Controllable emissions		71.3	
Fires		21.7	

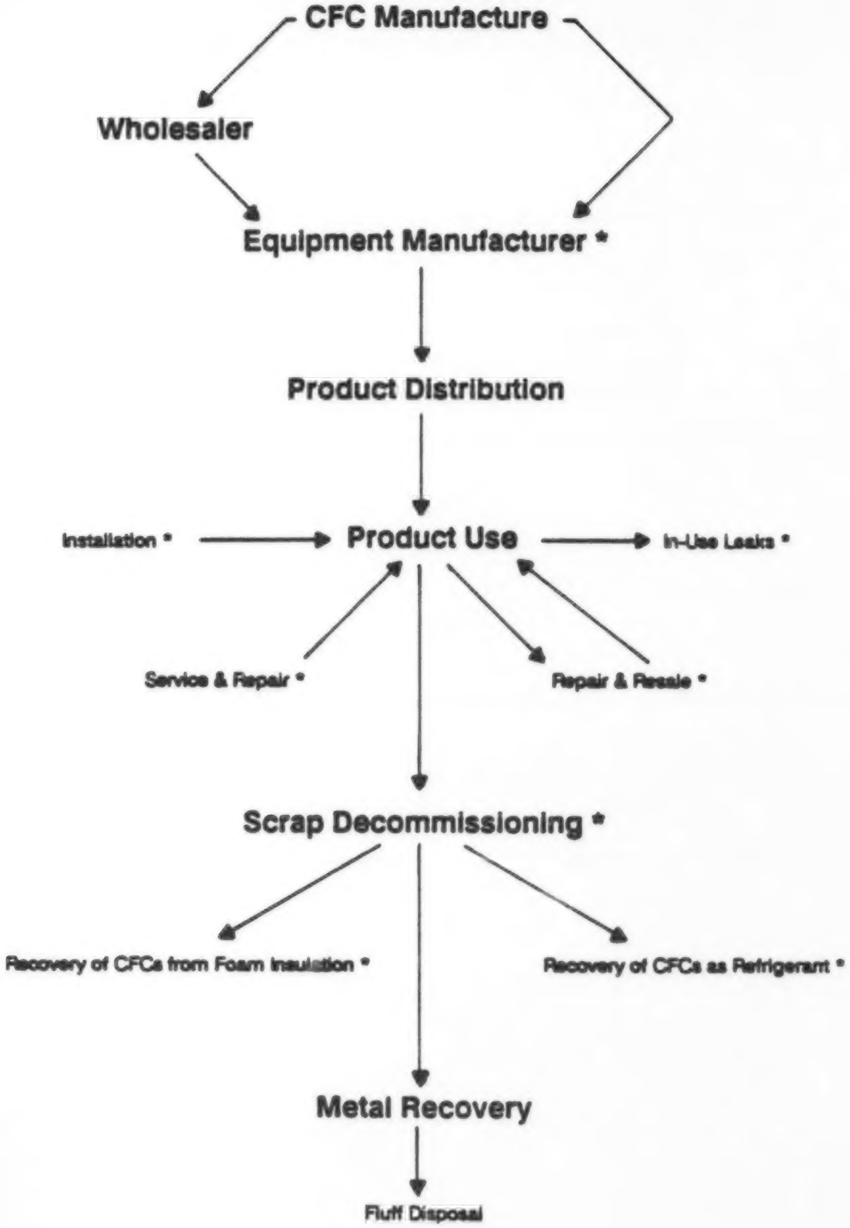
TABLE 2.14 - CFCs Used in Sterilization

CFC Use Sector	Primary CFC Used	Quantity Used in Canada (1987) tonnes/yr	Manufacturer and Distributor	End User
Sterilization	12 (as a mixture of ethylene oxide - 12%, and CFC 12 - 88%)	532	Linde	Various hospitals

TABLE 2.15 - CFCs Used in Aerosols

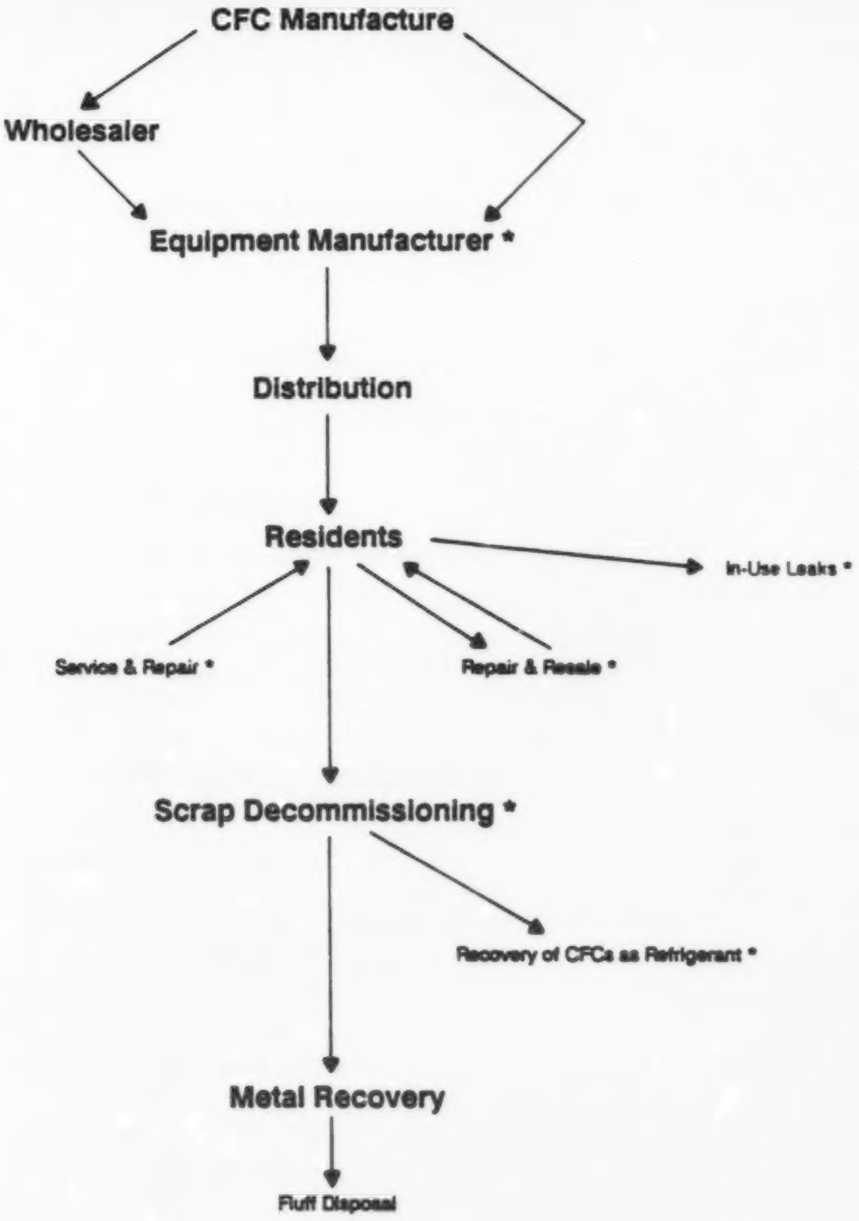
CFC Use Sector	Primary Type	Quantity of CFC Used in Canada (1987) tonnes/yr	Sample Companies Contacted
Aerosols		2,180.0	
Slurrying Agent	11, 12, 113, 114	1,329.8	
Propellant	12, 114	682.2	ShredTech MOE
Other		174.4	
Solvent	11, 113	43.6	

FIGURE 2.1 - Commercial Refrigeration and Air Conditioning


CFC Manufacture
Wholesaler
Equipment Manufacturer *
Product Distribution
Installation *
Product Use
In-Use Leaks *
Service & Repair *
Repair & Resale *
Scrap Decommissioning *
Recovery of CFCs from Foam Insulation *
Recovery of CFCs as Refrigerant *
Metal Recovery
Fluff Disposal

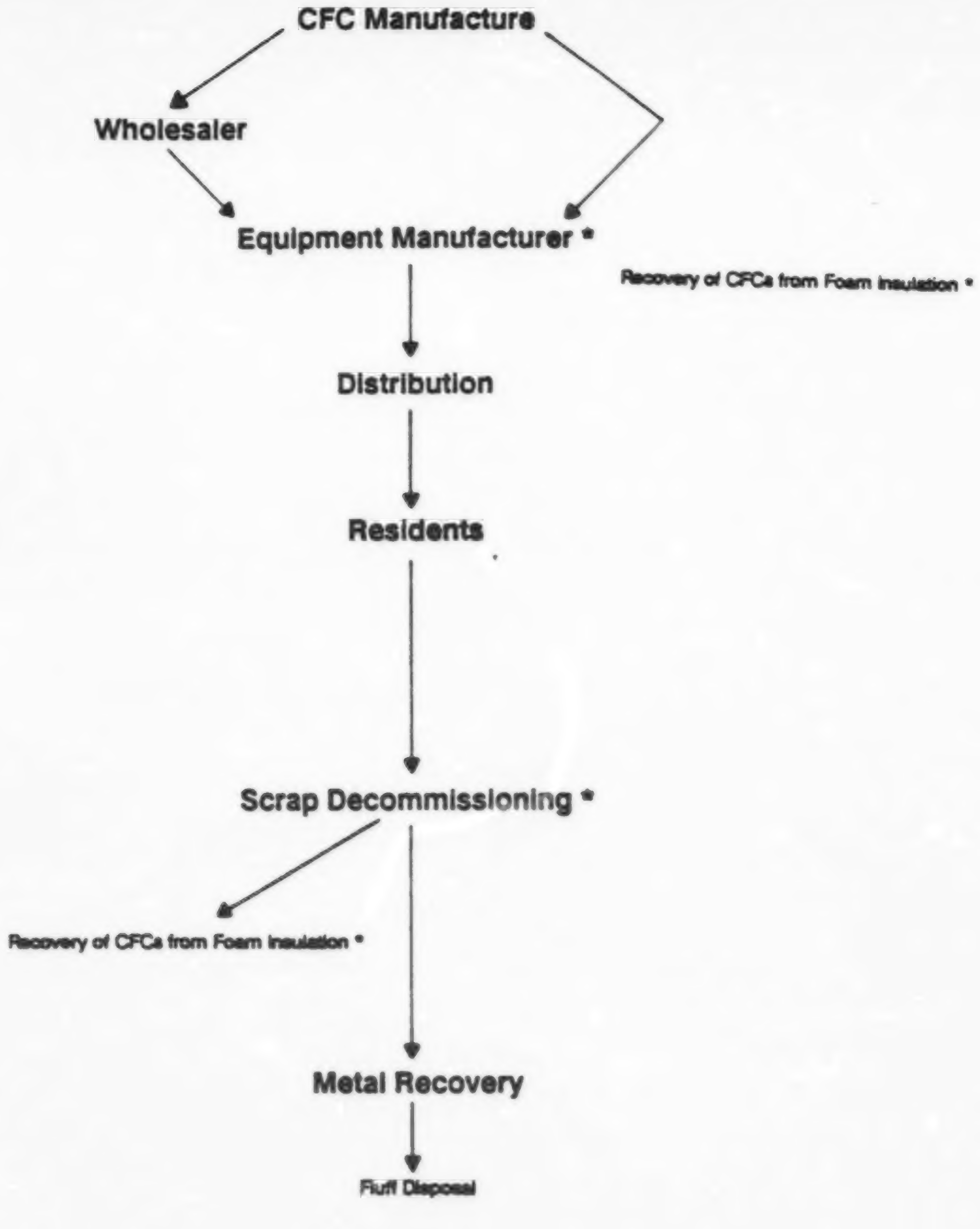
* CFC Losses or Potential Losses

FIGURE 2.2 - Domestic Refrigerators/Freezers - CFC 12


CFC Manufacture
Wholesaler
Equipment Manufacturer *
Distribution
Residents
In-Use Leaks *
Service & Repair *
Repair & Resale *
Scrap Decommissioning *
Recovery of CFCs as Refrigerant *
Metal Recovery
Fluff Disposal

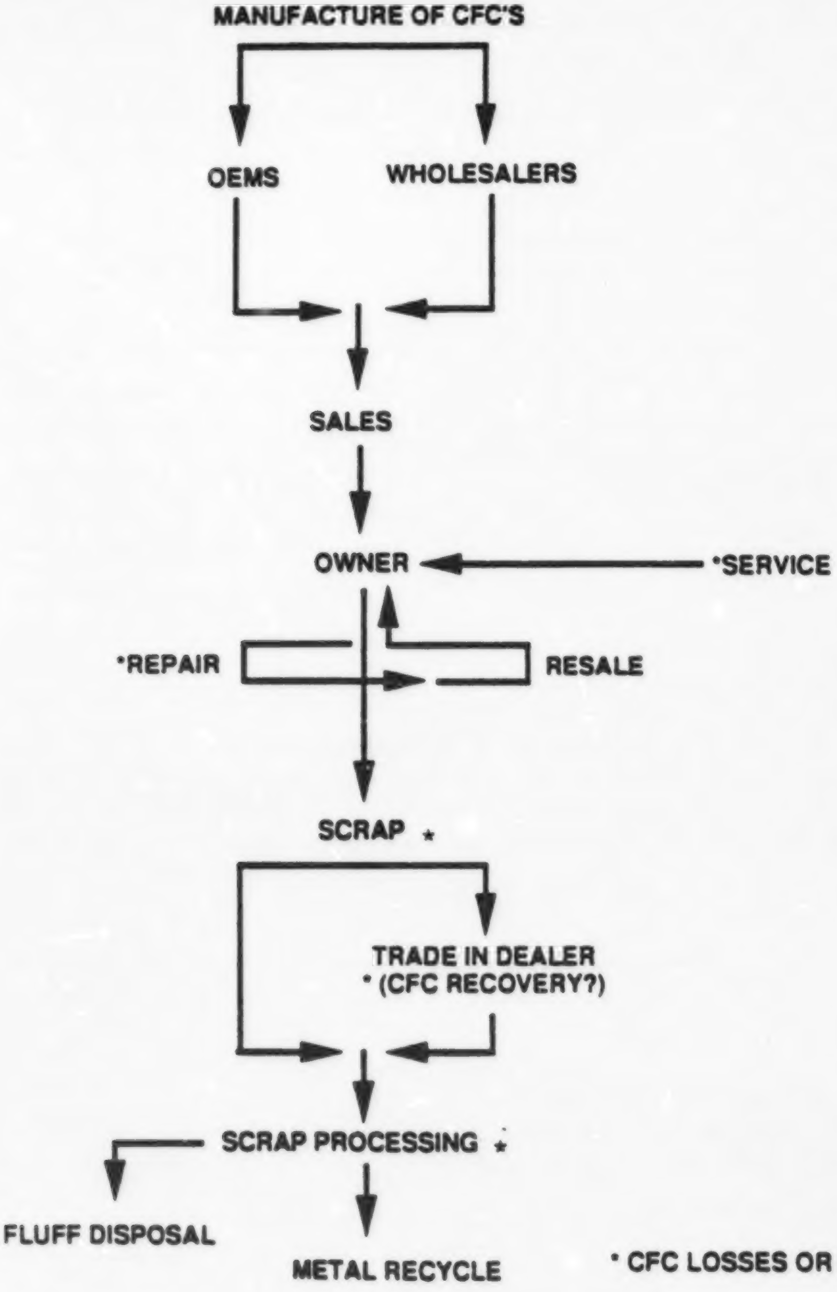
* CFC Losses or Potential Losses

FIGURE 2.3 - Domestic Refrigerators/Freezers - CFC 11


CFC Manufacture
Wholesaler
Equipment Manufacturer *
Recovery of CFCs from Foam Insulation *
Distribution
Residents
Scrap Decommissioning *
Recovery of CFCs from Foam Insulation *
Metal Recovery
Fluff Disposal

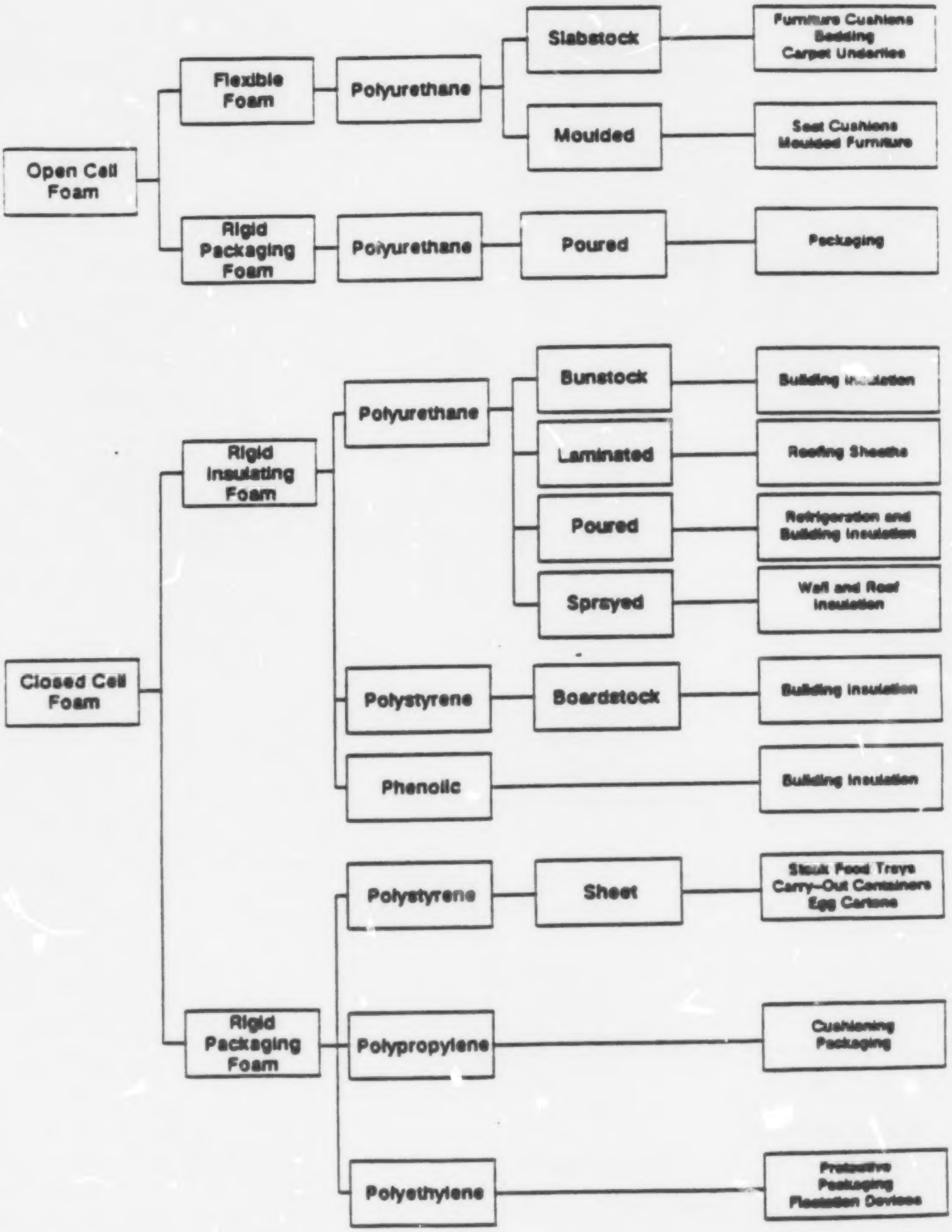
* CFC Losses or Potential Losses

FIGURE 2.4 - Mobile A/C CFC 12


MANUFACTURE OF CFC'S
OEMS
WHOLESALERS
SALES
OWNER
*SERVICE
*REPAIR
RESALE
SCRAP *
TRADE IN DEALER
* (CFC RECOVERY?)
SCRAP PROCESSING *
FLUFF DISPOSAL
METAL RECYCLE

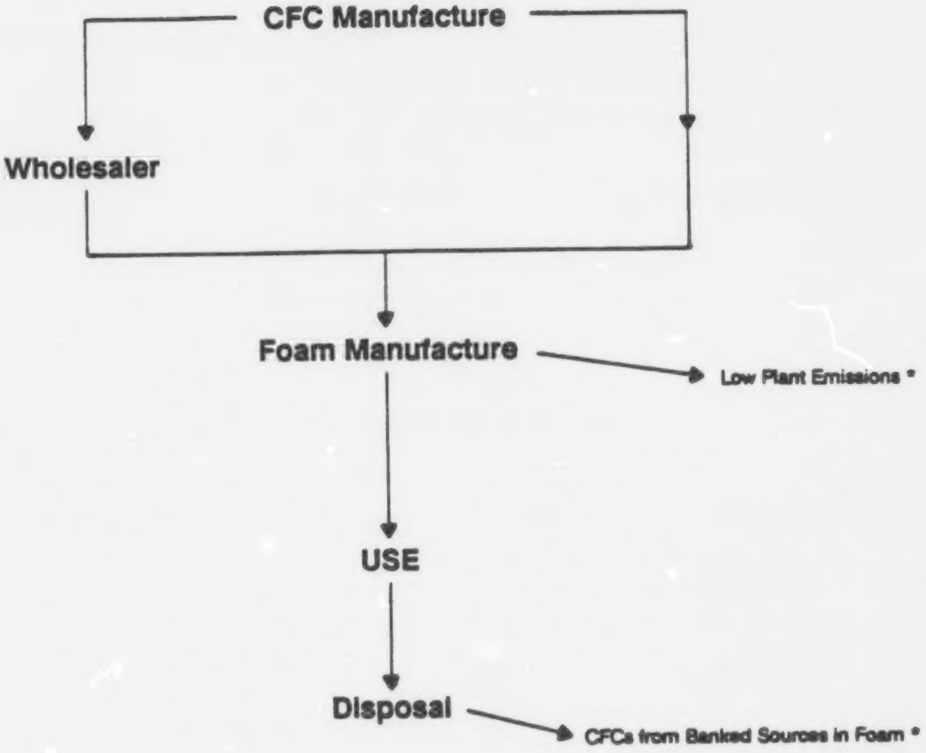
* CFC LOSSES OR POTENTIAL LOSSES

FIGURE 2.5 - Types and Major Uses of CFC Blown Foam


Open Cell Foam
Flexible Foam
Polyurethane
Slabstock
Furniture Cushions
Bedding
Carpet Underlies
Moulded
Seat Cushions
Moulded Furniture
Rigid Packaging Foam
Polyurethane
Poured
Packaging
Closed Cell Foam
Rigid Insulating Foam
Polyurethane
Bunstock
Building Insulation
Laminated
Roofing Sheaths
Poured
Refrigeration and Building Insulation
Sprayed
Wall and Roof Insulation
Polystyrene
Boardstock
Building Insulation
Phenolic
Building Insulation
Rigid Packaging Foam
Polystyrene
Sheet
Stock Food Trays
Carry-Out Containers
Egg Cartons
Polypropylene
Cushioning
Packaging
Polyethylene
Protective
Packaging
Floatation Devices

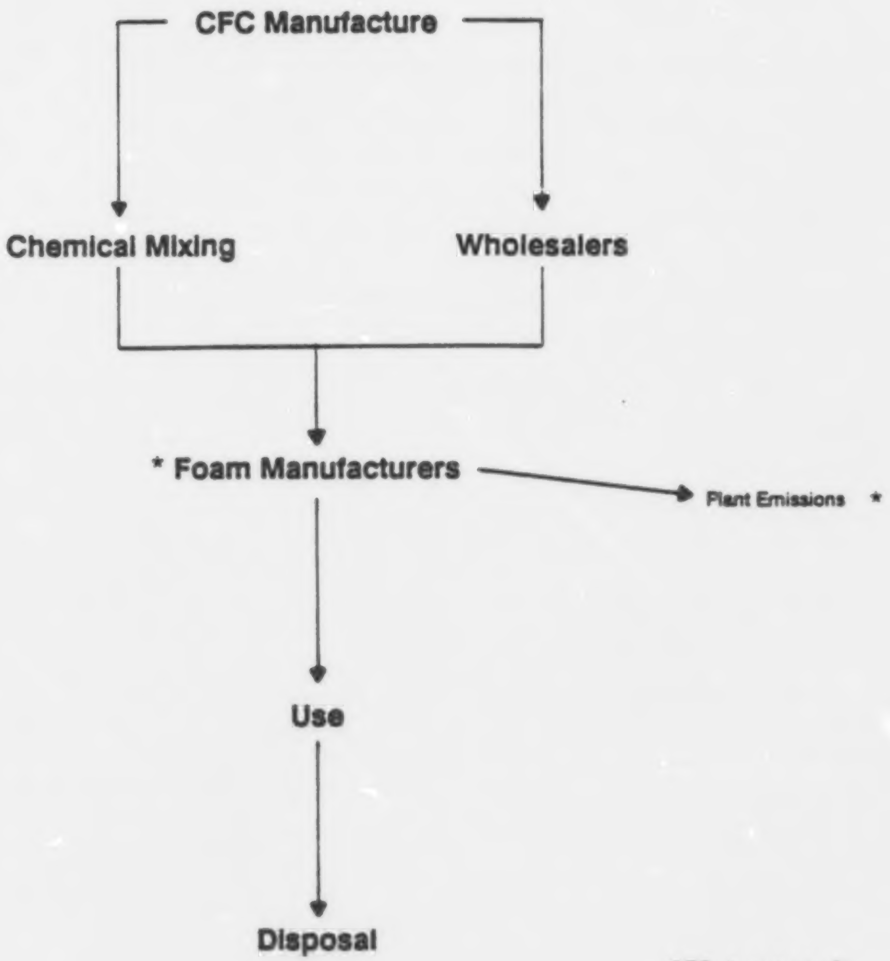
Source: ICF Incorporated, 1989

FIGURE 2.6 - Rigid Foam Packaging and Insulation


CFC Manufacture
Wholesaler
Foam Manufacture
Low Plant Emissions *
USE
Disposal
CFCs from Banked Sources in Foam *

* CFC Losses or Potential Losses

FIGURE 2.7 - Flexible Foam (Slabstock and Moulded)


CFC Manufacture
Chemical Mixing
Wholesalers
* Foam Manufacturers
Plant Emissions *
Use
Disposal

CFC Losses *

FIGURE 2.8 - Solvent Degreasing (CFC 113)

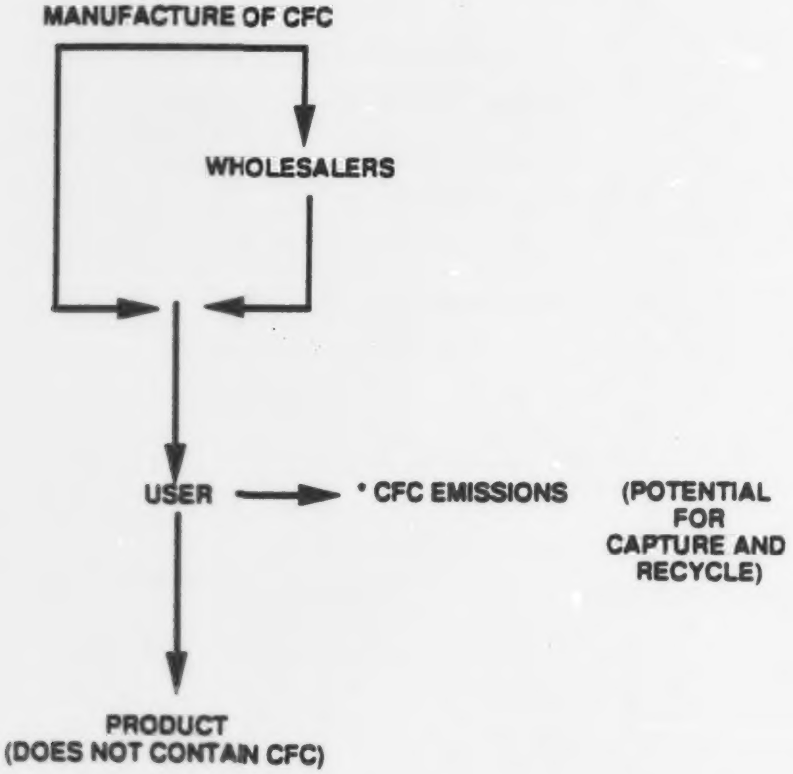

MANUFACTURE OF CFC
WHOLESALERS
USER
* CFC EMISSIONS
(POTENTIAL FOR CAPTURE AND RECYCLE)
PRODUCT (DOES NOT CONTAIN CFC)

FIGURE 2.9 - Fire Extinguishers (Portable Halon 1211)

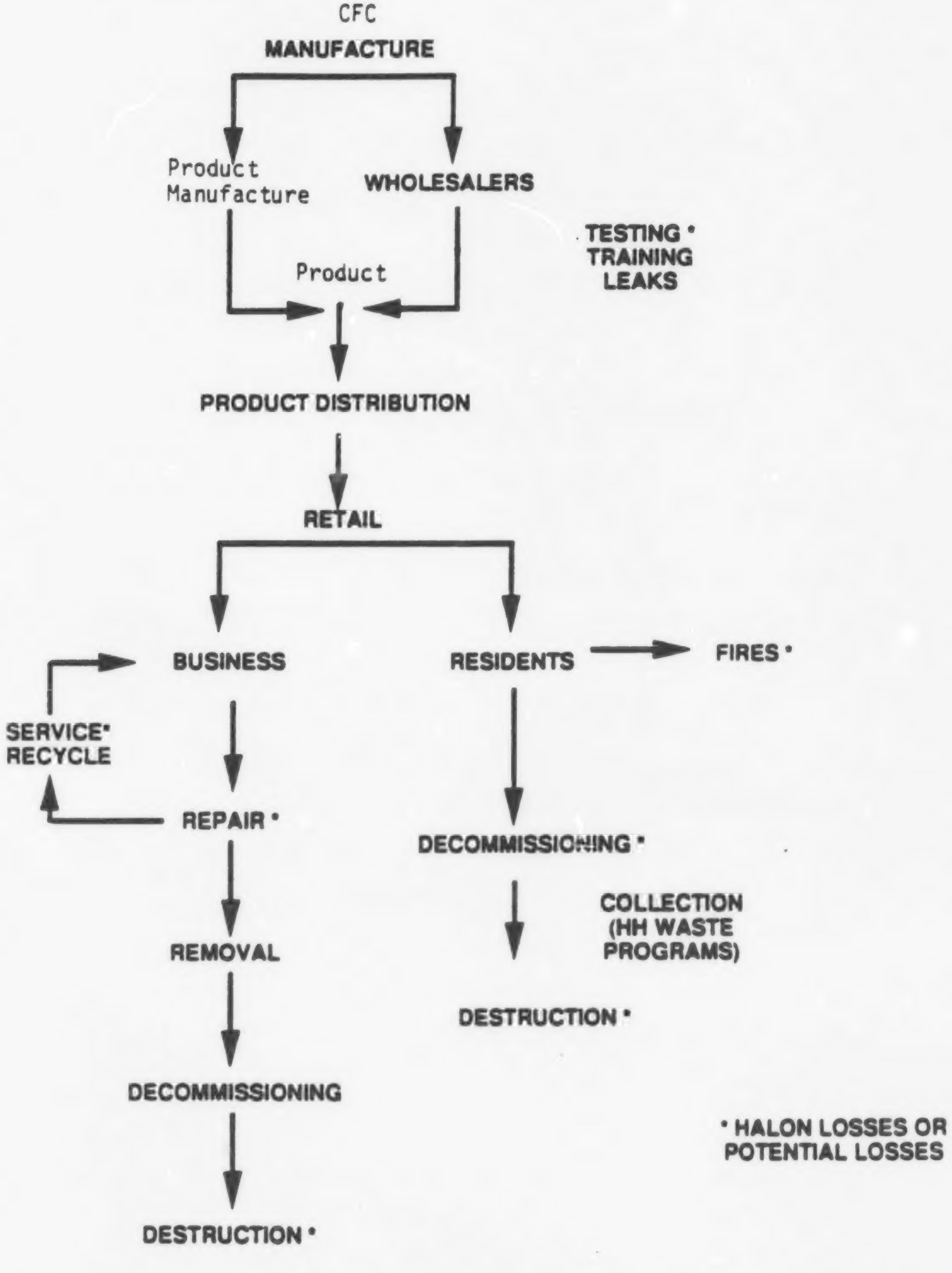

CFC
MANUFACTURE
Product
Manufacture
WHOLESALERS
TESTING *
TRAINING
LEAKS
Product
PRODUCT DISTRIBUTION
RETAIL
BUSINESS
RESIDENTS
FIRES *
SERVICE*
RECYCLE
REPAIR *
DECOMMISSIONING *
COLLECTION
(HH WASTE
PROGRAMS)
REMOVAL
DESTRUCTION *
DECOMMISSIONING
DESTRUCTION *
* HALON LOSSES OR
POTENTIAL LOSSES

FIGURE 2.10 - Fire Extinguishers
(Halon 1301 Total Flooding in Cabinet Systems)

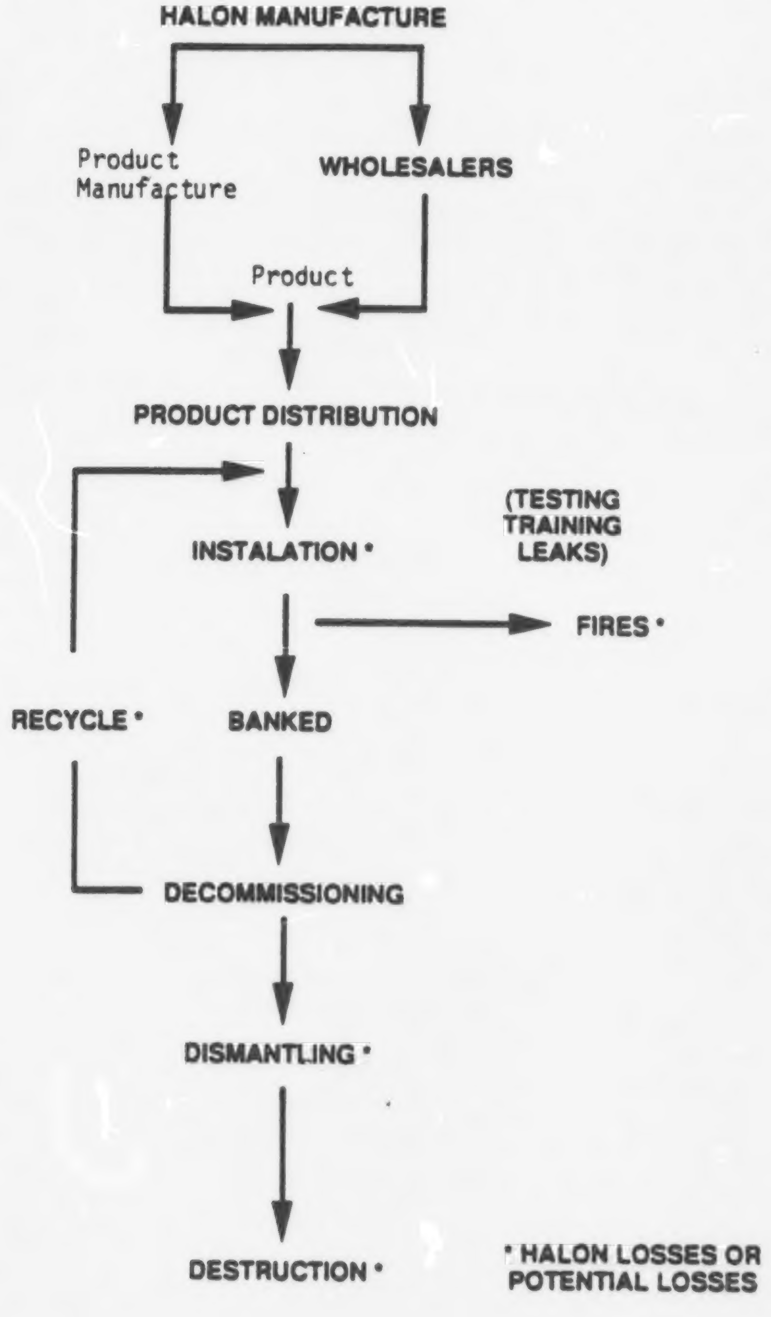
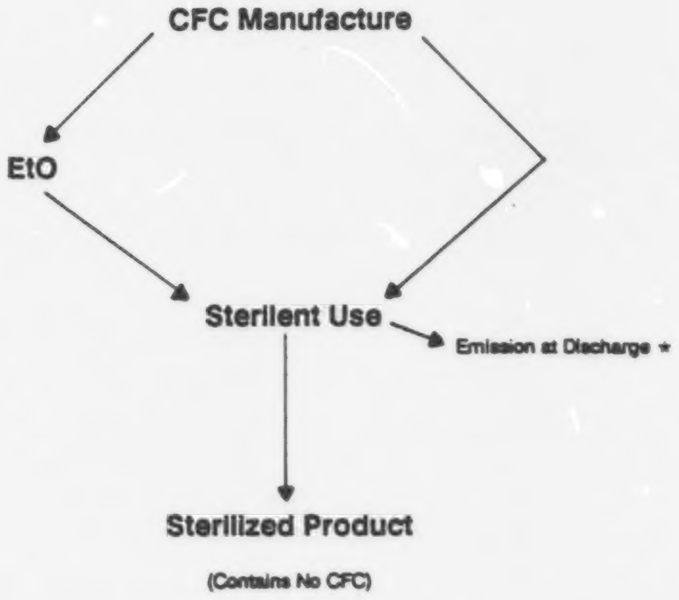
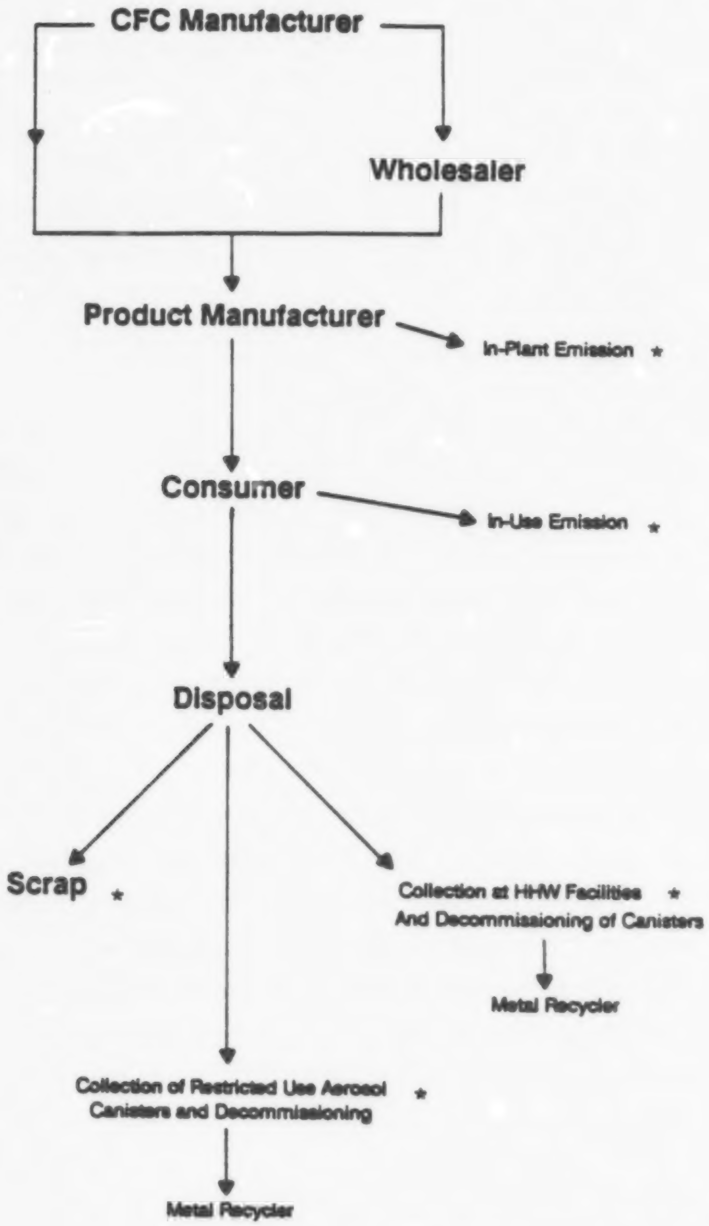

HALON MANUFACTURE
Product Manufacture
WHOLESALERS
Product
PRODUCT DISTRIBUTION
INSTALATION *
(TESTING TRAINING LEAKS)
FIRES *
RECYCLE *
BANKED
DECOMMISSIONING
DISMANTLING *
DESTRUCTION *
* HALON LOSSES OR POTENTIAL LOSSES

FIGURE 2.11 - Sterilant Gases


CFC Manufacture
EtO
Sterilent Use
Emission at Discharge *
Sterilized Product
(Contains No CFC)

* CFC Losses

FIGURE 2.12 - Aerosols


CFC Manufacturer
Wholesaler
Product Manufacturer
In-Plant Emission *
Consumer
In-Use Emission *
Disposal
Scrap *
Collection at HHW Facilities *
And Decommissioning of Canisters
Metal Recycler
Collection of Restricted Use Aerosol *
Canisters and Decommissioning
Metal Recycler

* CFC Losses or Potential Losses

3. ALTERNATIVE CFC RECYCLING SYSTEMS

3.1 Evaluation of Portable Recycling and Recovery Units

Table 3.1 outlines some of the currently available equipment for the recovery of CFCs. As shown in the Table, there are a number of companies involved in the business, with prices for recovery equipment ranging from as low as $1,200 to as high as $50,000 (U.S.$). In general, the information available from the companies was lacking in terms of technical detail. In most cases, the literature loosely mentions the method of recycling as either filtration or distillation.

In the case of filtration, the used refrigerant is passed through a filter to purify it from oils, acids, and particulates. The purified refrigerant is then pumped into a storage tank of varying capacity and is ready for disposal or reuse. Regular filter change is required to maintain purification. However, the literature does not mention frequency and costs involved. Almost no details were available on how "distillation" is used as a method of purifying CFCs. Most likely, it is somewhat different from what a chemical engineer would envision as a typical distillation process.

Compression/condensation is also used as a method of recycling CFCs by one company, Hunter Environmental. With this device, a mixture of CFC 12 and ethylene oxide, normally used to sterilize medical equipment, is collected and combined with water and an acid catalyst. The ethylene oxide is converted into an antifreeze that is easily removed. The remaining gas mixture, consisting of CFC, air and water vapour, is then condensed into a 60-80% CFC liquid that is recycled for blending with new ethylene oxide.

In terms of capability of handling different freons, most of the equipment can handle CFC 12, 502, HCFC 22 and 500. This can be compared with the Union Carbide Molecular Sieve Technology which has been tested with CFC 11, 12, 113, HCFC 22 and 123, and HFC 134a. However, unlike Blue Bottle™ technology, when vampires are utilized for different types of CFCs, these recovery units must be pumped out to purge out residual gas before new CFCs are introduced. In this respect, Blue Bottle™ can be used to compliment vampire units as an add-on. A direct comparison of the molecular sieve technology against the existing technologies was not done in this project. Because of differences in the nature of the two methods, it would have been inappropriate. Also, the fact that the sieve technology would have a central recycling/regeneration center while the existing equipment is an all inclusive unit (i.e. capture and recycle) would make cost comparisons difficult.

TABLE 3.1 - Existing Alternate Technologies for CFC Recovery

	Refrigerant										
Company	CFC 11	CFC 12	CFC 113	CFC 114	CFC 115	CFC 502	HCFC 22	Other CFC's	Method	Cost (US $)	
Applied Ecological Systems		X				X	X	500,134a 13B1	Filter	1200-1400	
Ener Craft, Inc.		X				X	X	500	Distill	8000-13000 24000	High Press Gas Low Press Gas
DAVCO Manufacturing, Co.	X	X		X		X	X	500	Distill	5000	
Klinge Products	X	X				X	X		N/A	7600-50000	
Murray Corp.		X							Filter/ Distill	2395	
Refrigerant Recovery Systems		X				X	X	500	Distill	2500-6800	
Van Steenburgh		X				X	X	500	Separator chamber	4400-6500	
Robinair Sealed Power Corp.		X									
Generex Industries Corp.		X				X	X		Filter		
Commercial Cooling								All Freons		3000-4000	
High Frequency Products, Inc.								Refrig from any A/C			
ThermaFlo	X	X				X	X		Filter		
FREOXX Hunter Environmental		X							Compression/ Condensation		Separates Ethylene Oxide from CFC 12

3.2 Comprehensive Recycling and Recovery Systems

One of the two manufacturers of CFC in Canada, DuPont announced it is willing to take back recovered CFC 11 and 12 from manufacturing, business and recycling operations for repurification(22). Two other companies are also set up in Ontario that may operate in conjunction with DuPont's efforts or independently to recycle some spent CFC. Both Anachemia(23) and Varnicolour(24) recycle select liquid CFCs, such as CFC 113 from cleaning operations (i.e. TF, TEF, TMF), and CFC 11 from large refrigeration/chilling units. At the present time, neither of these companies is apparently able to accept CFC 12 or others which are gaseous at ambient temperature. Anachemia did indicate that they may soon be retrofitting to be able to purify gaseous CFCs as well, but that this is a costly addition to their current system. It is apparent that equipment that can purify liquid CFCs would require significant alteration to handle gases.

In the U.S., National Refrigerants Inc., will offer a service in partnership with the wholesale outlets of United Refrigeration Inc. to recover and reclaim refrigerants from contractors and building owners and offer pure replacements(29). They maintain that current on-site recycling machines cannot guarantee quality without analysis and off-specs CFCs could cause problems with equipment reliability, operating efficiencies, warranties and contractor liabilities. The recovery and reclamation services include:

(1) returnable cylinders ranging from 40 lb, 100 lbs, 1 ton to 40,000 lb trailer transfer containers. These cylinders will be clearly colour coded as to the type (re ARI Standards) and market "used refrigerant".

(2) Refrigerant transfer units to pump down systems and which are capable of removing liquid and vapour.

(3) CFC reprocessing (via pressure distillation) at facilities in Bridgeton, N.J., to military specifications.

(4) analytical services to evaluate if refrigerant needs to be reprocessed; container for samples will be supplied to contractors.

(5) pick-up at United Refrigeration outlet or at the job-site for larger jobs, and delivery to company's reprocessing facility.

(6) reprocessing of both low pressure (CFC 11 and 113) and high pressure (12, 22, 114, 500 and 502). It cannot handle mixed batches.

The contractor is assured that he can purchase a replacement charge from National Refrigerants, which will be an important aspect as production cutbacks become more severe.

Internationally, ICI Chemicals and Polymers in the U.K. and throughout Europe have announced a major extension to the recycling and recovery services they have already been offering their customers for several years. CFCs accepted for recycling include 11, 12, 22, 502, and HCFC 22. ICI would provide customers with colour coded drums and cylinders for storage of contaminated CFCs. CFCs will then be accepted by ICI for recovery and repurification. Material not suitable for recovery will be disposed of at a small charge to the customer(33).

BOC has also announced that it would provide special cylinders in which spent CFC could be stored. The cylinders would be collected by BOC and the refrigerant reclaimed in a two stage process. First, the gas would be cleaned by BOC, then it would be repackaged in 1 tonne containers and shipped to DuPont in the Netherlands for reprocessing to ensure a factory grade product. BOC would then receive back the repacked CFC for resale. Unsuitable CFCs would be disposed of in an "environmentally safe fashion". This assures that the loop of manufacturer, distributor user and reprocessor is closed.(34).

3.3 Alternative Recovery Systems for Dilute Gas Streams

For dilute gas streams, adsorption technology has been used in the past, but primarily with carbon. According to work at Linde, carbon tends to accumulate a residual upon regeneration, causing fouling and decreased efficiency when compared with mol sieve (see Section 4). Another system recently announced for CFC recovery from air streams is a membrane technology employing selective layers of a rubbery polymer on a polysulfone substrate. The selection of rubbery polymers, the manufacturer contends, is suited for CFC separation because CFCs permeate the membrane fifty times faster than air. Membrane Technology and Research Inc. (California) claims that their system is simple and relatively inexpensive and has a competitive niche for cleaning vent streams with a CFC content of 0.1-20%, where traditional carbon adsorption is increasingly expensive above 0.1% and compression condensation is practical only down to about 10%(31).

4. EVALUATION OF LINDE CFC RECYCLING TECHNOLOGY

4.1 CFC Capture Efficiency

4.1.1 Evaluation Protocol

In order to measure the capture efficiency of the proprietary molecular sieve, an experimental protocol was designed. The objective of this protocol was to determine the affinity for adsorption of the various CFCs under different conditions. The data from these tests provided a relative comparison of the specific adsorption capacity of the various CFCs as well as an absolute design loading.

The compounds tested were:

CFC 11
CFC 113
HCFC 123

CFC 12
HCFC 22
HFC 134a

For each emission scenario, a separate protocol was developed to reflect the expected conditions. CFC detection was accomplished by utilizing two Miran IR spectrophotometers. Calibration of the instruments was accomplished by using a closed loop calibration system (see Figure 4.1), consisting of an air pump, septum, stainless steel tube fittings and teflon tubing.

Known volumes of the CFC in question were injected through the septum by use of a syringe, circulated through the cell by means of the pump, and the response was recorded in mV.

The concentration for the gas or liquid CFC was determined by the following formulae:

For Liquids:

$$C \text{ (ppm)} = \frac{pV}{M} \times \frac{(RT)}{(P)} \times \frac{10^3}{5.64}$$

where:

V = Sample volume in microlitres. (Total volume of cell and calibration system = 5.64 litres)

p = Liquid density (g/cm^3)

M = Molecular weight of sample

$\frac{(RT)}{(P)}$ = Molar volume of gas (24.4 at 25°C)

For Gases:

$$C \text{ (ppm)} = \frac{V}{5.64}$$

where:

V = Sample volume in microlitres

Figure 4.2 illustrates the experimental apparatus used for the prompt emission tests of liquid CFCs (11, 113, 123).

The procedure employed for each test is as follows:

(i) A stainless steel canister containing ~ 750 g of mol sieve was installed as per the schematic in Figure 4.2.

(ii) The calibrated Miran IR Analyzers were interfaced with Campbell Scientific 21XL Data Logger. The 21 XL was programmed to take mV readings every second and output averages every minute to a SM-716 data storage module.

(iii) A known volume of CFC was charged to the impinger and it was placed in a cooling bath with either water or ice-water.

(iv) The dilution nitrogen flow was initiated at a flowrate of approximately 6-12 L/minute (depending on the specific test). The impinging nitrogen flow was started at the same time at 150-300 mL/min. Once the baseline was set at the desired concentration (1,000 to 5,000 ppmv) the flow was diverted through the mol sieve bed.

(v) The flow was continued until the first detection of breakthrough on the effluent Miran IR Analyzer. At this time, the flow was suspended, the canister disconnected and the change in weight was measured and recorded.

(vi) The canister was then reconnected and the flow was resumed until the adsorption appeared to be at equilibrium. At this time, the canister was disconnected and the change in weight was measured and recorded.

(vii) The test was terminated and the data from the SM-716 storage module was transferred to comma delineated ASCI files on the computer and processed into breakthrough curves.

The apparatus was slightly modified when gaseous CFCs were used (12, 22, 134a) as presented in Figure 4.3. The procedure used for these tests was essentially the same, except that a pressurized cylinder of CFC was used as well as an accumulator vessel.

The banked emission adsorption apparatus, as shown in Figure 4.4, was considerably simpler than its prompt counterparts. Since a stream of 100% CFC was used, only one Miran was used and the tests normally took less than 5 minutes to complete. The procedures were:

(i) A known flowrate of 100% CFC was measured from a pressure vessel and diverted through a stainless steel canister containing ~ 750 g of molecular sieve.

(ii) The effluent concentration was monitored by a Miran IR Analyzer.

(iii) The CFC flow was continued until the first detection of breakthrough in the effluent. At this time, the flow was suspended and the canister was disconnected , the change in weight measured and recorded.

(iv) The canister was reconnected and the flow was resumed for an additional few minutes. The canister was then disconnected and weighed.

(v) The test was terminated and the data from the SM-716 Storage Module was transferred to comma delineated ASCI files on the computer and processed breakthrough curves.

4.1.2 Prompt Emission Adsorption Results

The results of the prompt emission adsorption tests are summarized in Table 4.1, while the breakthrough curves are presented in Appendix 7. CFCs 11, 12 and 113 were tested at these standard conditions, as well as the intermediate compound HCFC 22 and the proposed alternatives, HCFC 123 and 134a.

The proprietary molecular sieve capacity for CFC 113 at 5,000 ppm and 12 or 6 L/min averaged 0.035 and 0.043 (g/g) respectively. The equilibrium capacities for the 12 and 6 L/min conditions averaged 0.066 and 0.079 (g/g) respectively. It should also be noted that the time to equilibrium was approximately two times the breakthrough time. This suggests a long, inefficient mass transfer front as illustrated in the CFC 113 breakthrough curves presented in Appendix 7.

Similarly, for CFC 11, the 12 and 6 L/min capacities were 0.074 and 0.068 (g/g) respective. The equilibrium capacity for the 12 L/min tests averaged 0.089 (g/g) with a sharper, but still meandering mass transfer front.

CFC 12 was also tested at 12 and 6 L/min, and the adsorptive capacity was found to be 0.045 and 0.052 (g/g) respectively . The equilibrium capacity for both flowrates was 0.066 (g/g). However, for CFC 12, the mass transfer front was slightly sharper than observed in the adsorption testing of the aforementioned CFCs. This is, perhaps, indicative of a better affinity for CFC 12 on the tested molecular sieve.

The intermediate compound, HCFC 22, showed breakthrough and equilibrium adsorptive capacities of 0.032 and 0.039 (g/g) respectively at 5,000 ppm and 12 L/min. In this case, the mass transfer front was significantly sharper (see Appendix 7).

Finally, two of the proposed alternatives were tested at the prompt emission conditions of 5,000 ppm and 12 L/min. Interestingly, the adsorptive capacities for HFC 134a and HCFC 123 were the highest recorded during the evaluation program. HCFC 123 breakthrough capacity was 0.081 (g/g) at 12 L/min, 5,000 ppm, while the equilibrium capacity was 0.125 (g/g). For HFC 134a at the same conditions, a breakthrough capacity of 0.054 (g/g) was observed. The mass transfer fronts in both cases were fairly direct and sharp.

4.1.3 Banked Emission Adsorption Data

HCFC 22, as well as CFC 12, are both used in banked applications, primarily in industrial, commercial and residential refrigeration. Consequently, these compounds were tested at 100% concentration and a flowrate of 6 L/min. The results showed very high adsorptive capacities for each refrigerant. CFC 12 averaged 0.151 (g/g) at a breakthrough time of 2.34 minutes, and 0.164 (g/g) at an equilibrium time of 4.42 minutes. HCFC 22's adsorptive capacity at a breakthrough time of 3.95 minutes was 0.129 (g/g), while, at an equilibrium time of 6.5 minutes, 0.140 (g/g) was recorded. The full results are presented in Table 4.2.

At these banked conditions, the exothermic nature of the adsorption was clearly evident. During adsorption, the surface of the canister became hot, reaching a temperature of 44°C. As the test continued, this heat front moved up the length of the canister in the direction of the CFC flow. This phenomenon proved useful as a means of demonstrating the Blue Bottle™ process. It could also potentially provide a qualitative measure of the degree of saturation of a canister.

4.1.4 Additional Adsorption Related Testing

As well as the aforementioned capacity/breakthrough testing, various other adsorption related tests were conducted throughout the project. These experiments were usually designed to help understand the nature of the internal mass transfer or extend and validate a particular theory. A summary of the results of this work follows.

Blue Bottle™ Bed Temperature Profiles

In an attempt to better understand the CFC adsorption heat transfer, a standard canister was retrofitted with three thermocouples. These thermocouples were positioned at one quarter, one half and three-quarter heights in the mol sieve bed. In addition, two thermocouples were installed in the influent and effluent fittings. From these sensors, an accurate bed temperature profile was generated for several different CFCs.

Figure 4.5 presents the temperature profile for adsorption of CFC 113 upon the tested sieve. Due to equipment malfunction, the exact flowrate and CFC concentration were unknown. However, the graph does provide some interesting qualitative data. Within one-half hour, the thermocouple in the first quarter of the bed heats up from 23.5 to 30°C, and slowly drops to between 25 and 26°C. The temperatures at one-half and three-quarters slowly increase to about 28°C, at which point they drop for about one hour. At approximately the time of breakthrough, the temperatures rise rapidly, reaching a maximum of ~ 30.5°C. Since surface cooling obviously affects the maximum temperature, a canister was insulated with several inches of fiberglass and exposed to 5,000 ppmv of CFC 113 at 12 L/min (CFC 113 Adsorption Test 19). The maximum temperature recorded at the canister effluent was approximately 35°C.

Another bed temperature profile was obtained for CFC 12 at 5,000 ppmv and 6 L/min (CFC 12 Adsorption Test 6 - see Figure 4.6). It can be seen that, as the adsorption front moves up the canister bed, the temperature increases, due to the exothermic reaction. The first thermocouple reaches to a maximum of 30°C within ~ 50 minutes of initiation of the flow, while the final thermocouple reaches a maximum of 29°C at the approximate time of breakthrough.

Molecular Sieve Milled to 0.7 mm

Approximately 2 kg of molecular sieve was ground and sieved to a particle size of between 0.6 and 0.841 mm to test if the increased surface area would augment mass transfer rates. A standard adsorption test of CFC 11 upon ground product was conducted (CFC 11 Adsorption Tests No. 6 and 7) in duplicate and the results are presented in Figures 4.7 and 4.8 The results showed that the 0.6 - 0.841 mm sieve did not perform as well as the large particles, giving breakthrough capacities of 0.041, compared to 0.074 (g/g) observed earlier. Moreover, from the curves, it can be seen that the mass transfer front appears flat and meandering, suggesting lower efficiency transfer. An adsorption temperature profile of the ground sieve bed was also conducted and the graph is presented in Figure 4.9.

Two Canisters in Series

In order to simulate a longer bed, two canisters were connected in series and exposed to CFC 113 at 5,000 ppmv at 12 L/min (CFC 113 Adsorption Tests No. 21 and 22). The results showed that the breakthrough capacity was unchanged for the two canister test.

TABLE 4.1 - Prompt Emission Test Summary

Test No.	CFC	Conc (ppmv)	Flowrate (L/min)	BT (min)	BT Capacity (g/g)	EQBM (min)	EQBM Capacity (g/g)	Comments
15	113	5056	12	60	0.036	125	0.055	
16	113	4774	6	150	0.043	350	0.077	
17	113	4817	12	60	0.034	261	0.076	
18	113	4899	6	150	0.043	371	0.081	
19	113	4714	12	42	0.023	NA	NA	Insulated Canister Temp Profile
20	113	4851	12	300	0.304	450	0.448	BPL 40 x 60 Mesh Carbon
21	113	4769	12	125	0.035	NA	NA	Two Canisters in Series
22	113	4874	12	115	0.033	NA	NA	Two Canisters in Series
3	11	5016	12	220	0.072	302	0.090	Baseline Erratic
4	11	4644	12	220	0.075	277	0.088	Baseline Erratic
5	11	5000	6	530	0.068	NA	NA	
6	11	4912	12	118	0.041	309	0.068	Selve ground to 0.6 - 0.841 mm d
7	11	5064	12	95	0.041	NA	NA	Selve ground to 0.6 - 0.841 mm d
1	12	5215	12	109	0.058	NA	NA	Baseline Erratic
2	12	5090	12	60	0.041	150	0.068	
3	12	5289	12	70	0.037	160	0.063	
6	12	5204	6	290	0.052	400	0.066	
1	22	4760	12	179	0.032	230	0.039	
2	22	4724	12	170	0.032	230	0.039	
1	123	4289	12	190	0.081	279	0.125	
2	123	4448	12	180	0.080	289	0.125	
1	134a	5050	12	170	0.052	240	0.064	
2	134a	4933	12	206	0.056	NA	NA	

TABLE 4.2 - Banked Emission Test Summary

Test No.	CFC	Conc (%)	Flowrate (L/min)	BT (min)	BT Capacity (g/g)	EQBM (min)	EQBM Capacity (g/g)
4	12	100	6	2.25	0.149	NA	NA
5	12	100	6	2.42	0.152	4.42	0.164
3	22	100	6	3.96	0.129	5.96	0.140
4	22	100	6	3.93	0.129	6.93	0.139

FIGURE 4.1 - Schematic Diagram of Closed Loop Calibration System

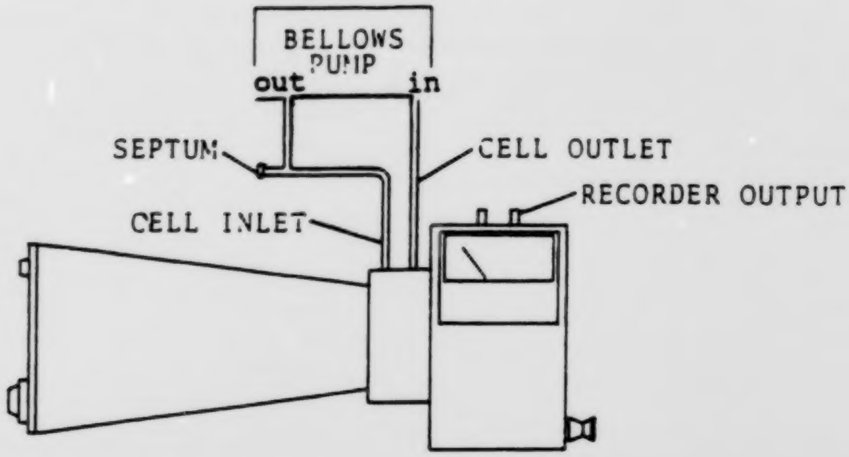

BELLOWS PUMP
out
in
SEPTUM
CELL OUTLET
RECORDER OUTPUT
CELL INLET

FIGURE 4.2 - Liquid CFC Prompt Emission Adsorption Test Apparatus

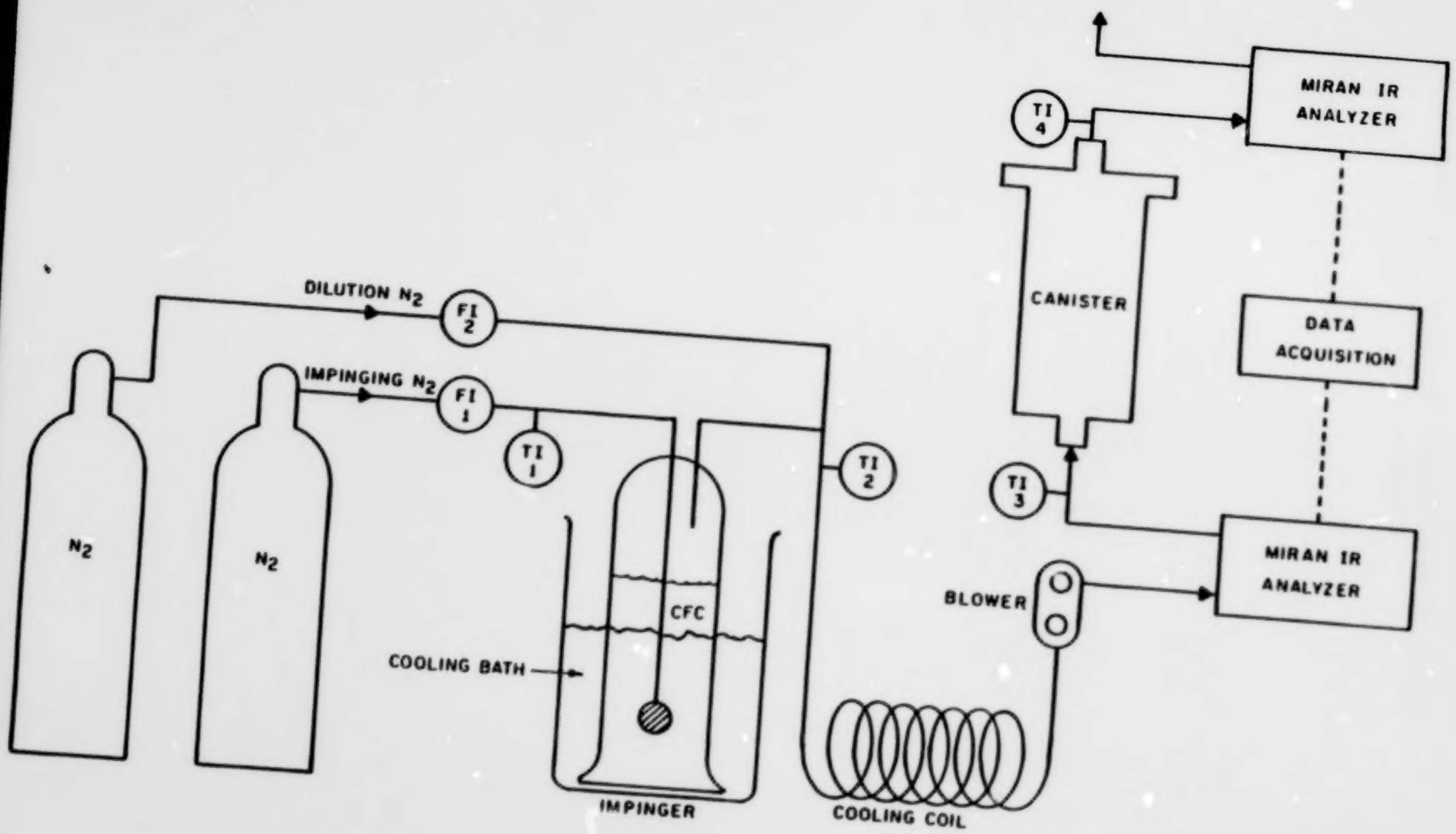

MIRAN IR ANALYZER
TI 4
CANISTER
DATA ACQUISITION
DILUTION N_2
FI 2
IMPINGING N_2
FI 1
TI 1
TI 2
TI 3
MIRAN IR ANALYZER
N_2
N_2
CFC
BLOWER
COOLING BATH
IMPINGER
COOLING COIL

FIGURE 4.3 - Gaseous CFC Prompt Emission Adsorption Test Apparatus

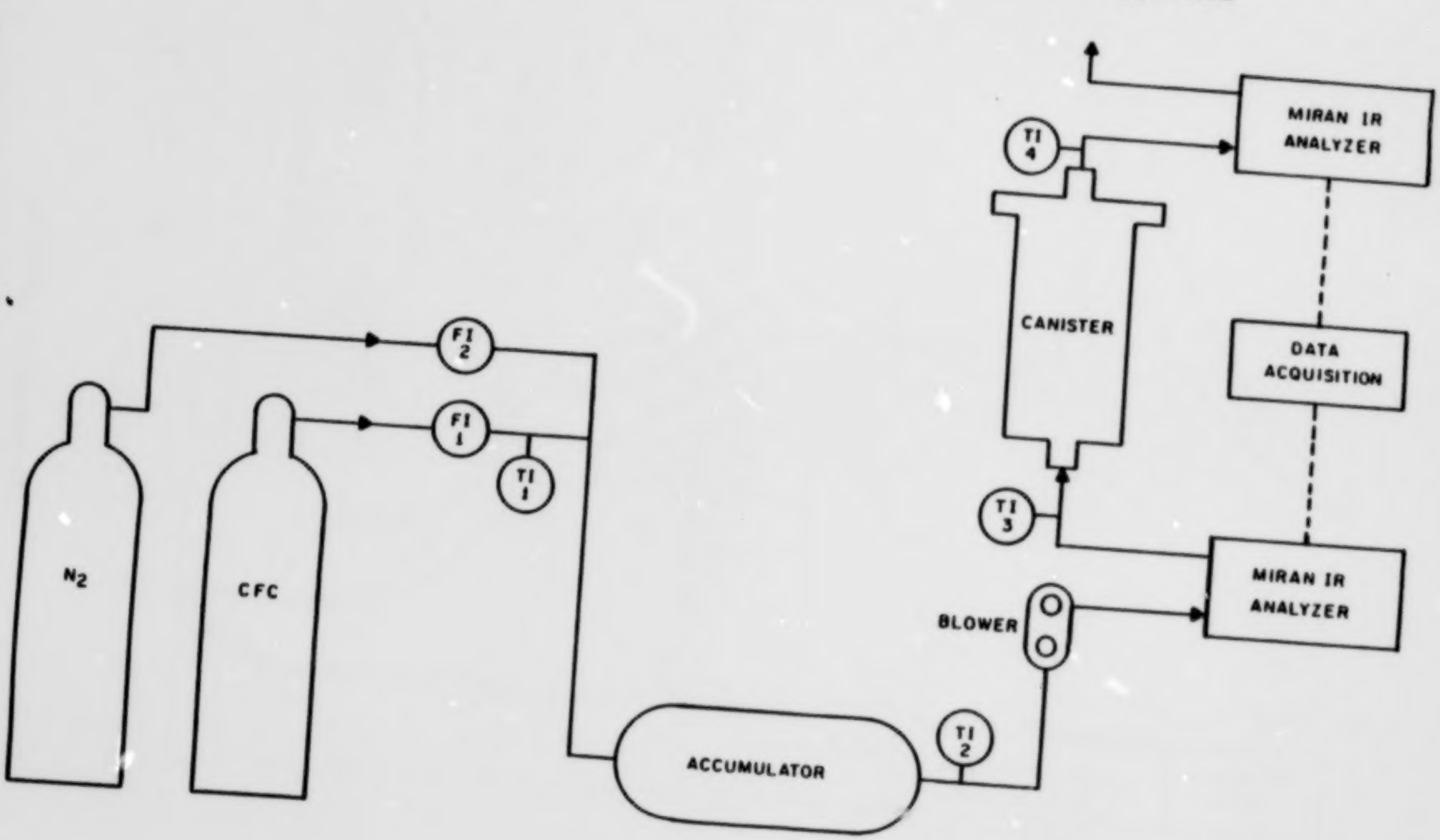

MIRAN IR ANALYZER
TI 4
CANISTER
DATA ACQUISITION
FI 2
FI 1
TI 1
TI 3
MIRAN IR ANALYZER
N2
CFC
BLOWER
TI 2
ACCUMULATOR

FIGURE 4.4 - CFC Banked Emission Adsorption Test Apparatus

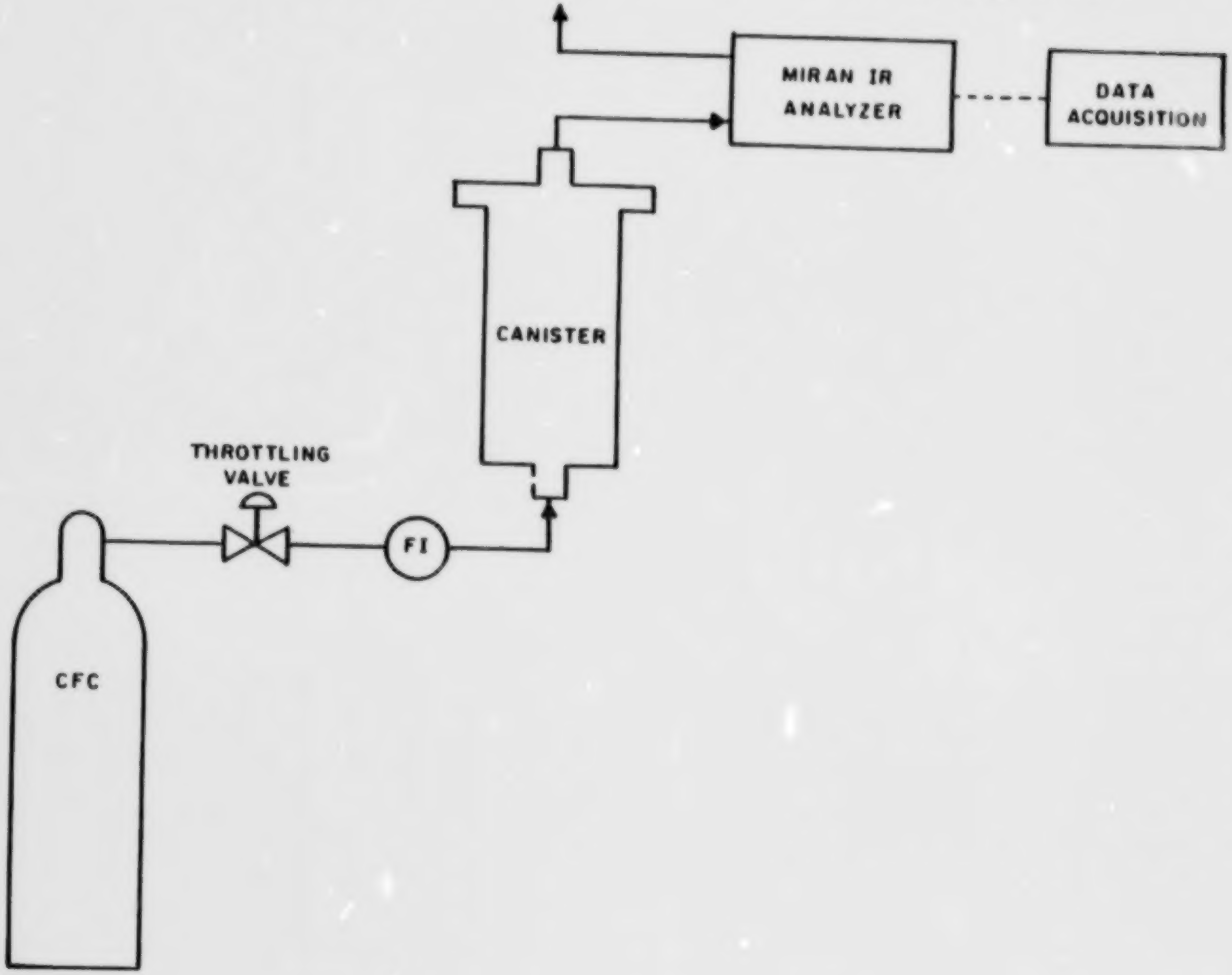

MIRAN IR
ANALYZER
DATA
ACQUISITION
CANISTER
THROTTLING
VALVE
FI
CFC

FIGURE 4.5 - CFC 113 Adsorption Test 9
Bed Temperature Profile

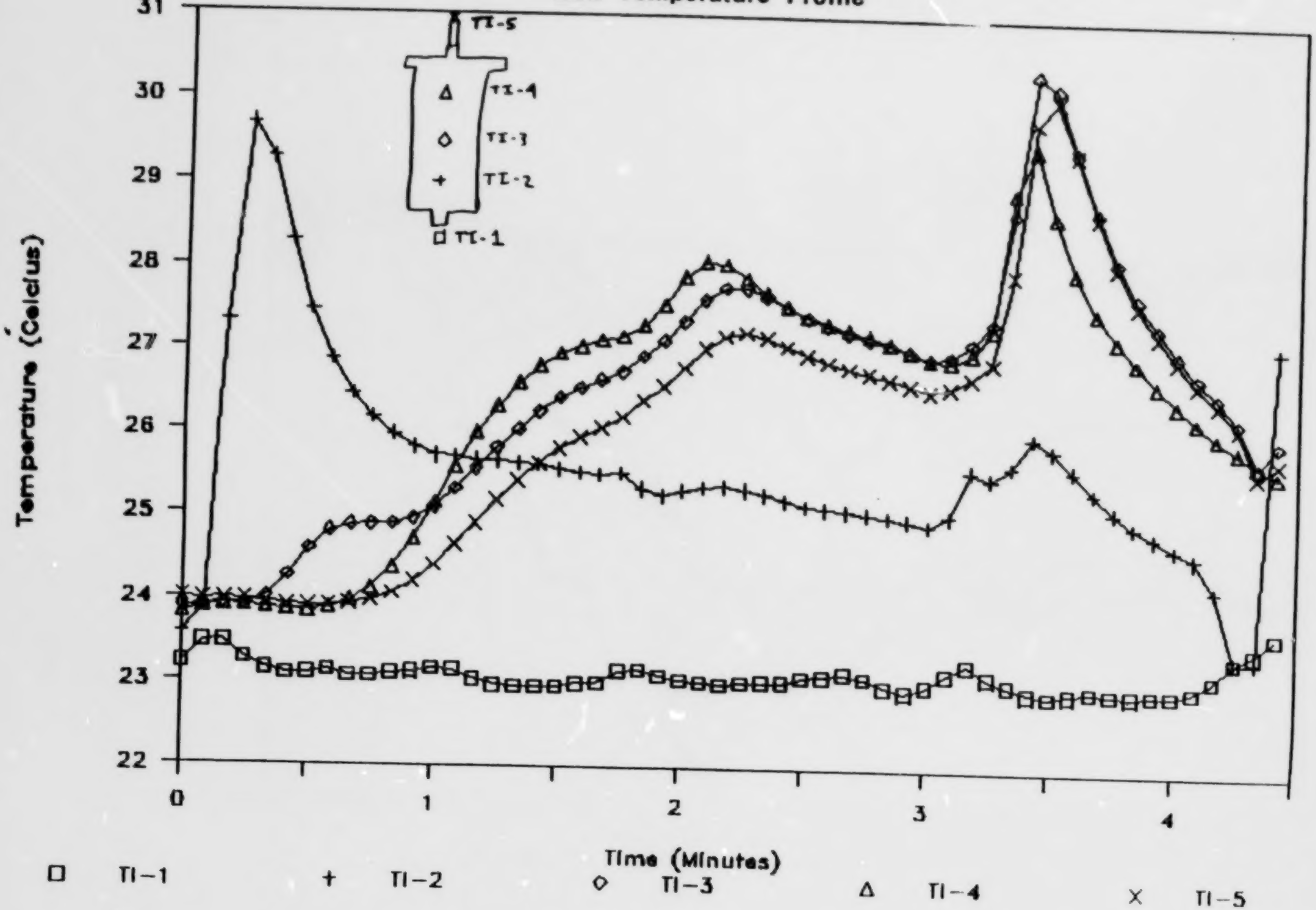


FIGURE 4.6 - CFC 12 Adsorption Test 6
Temperature Profile

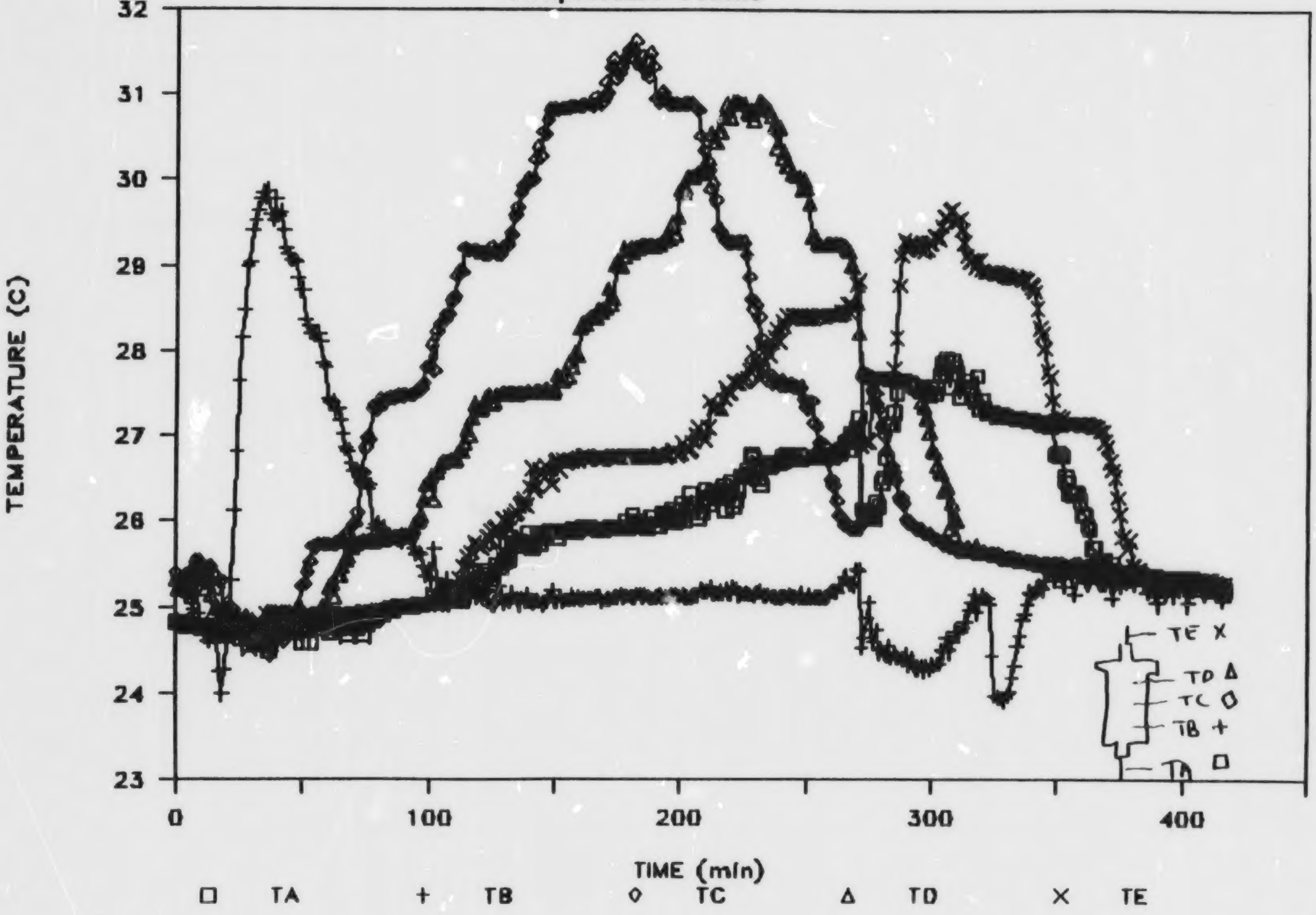


FIGURE 4.7 - CFC 11 Adsorption Test 6

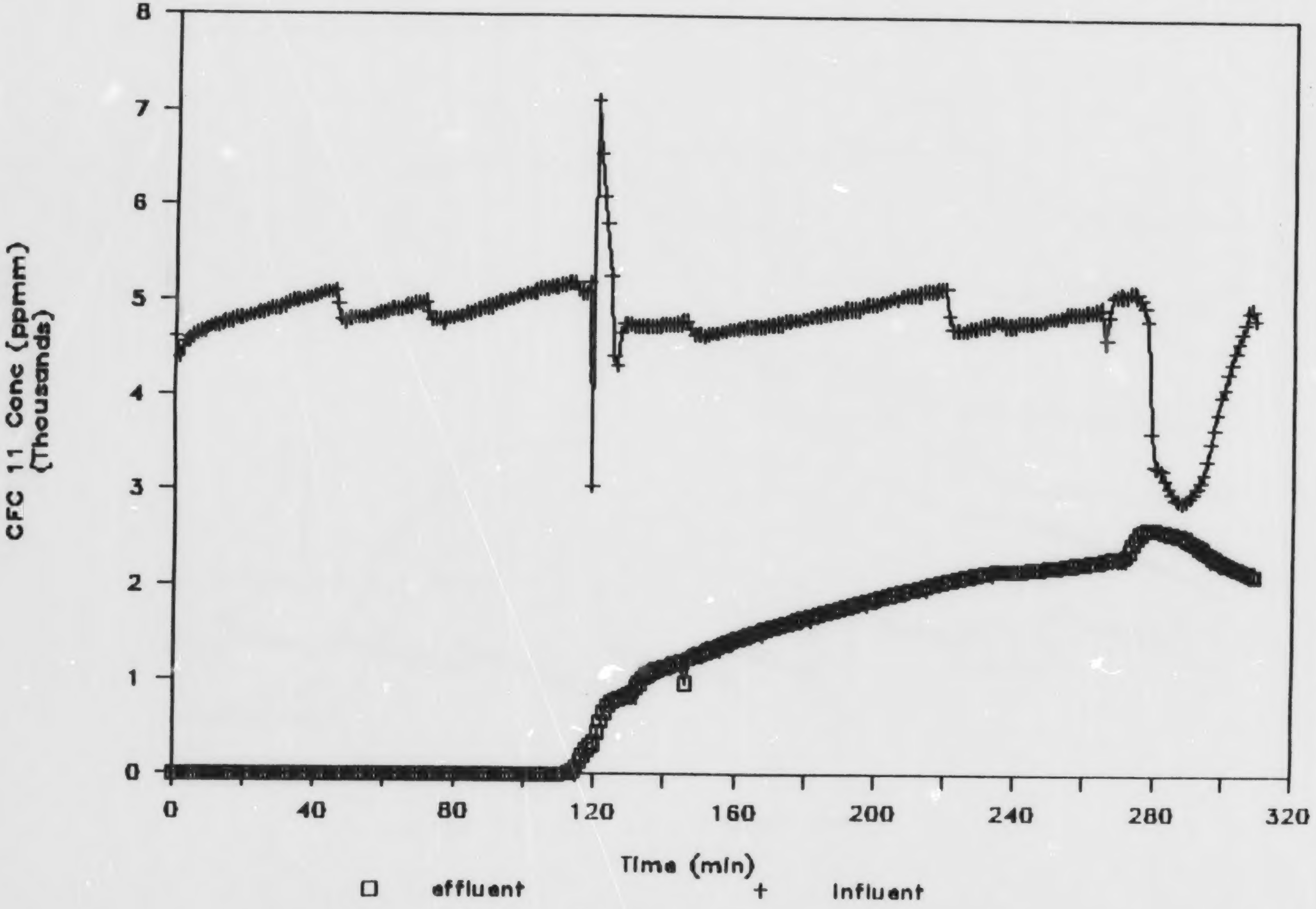


FIGURE 4.8 - CFC 11 Adsorption Test 7

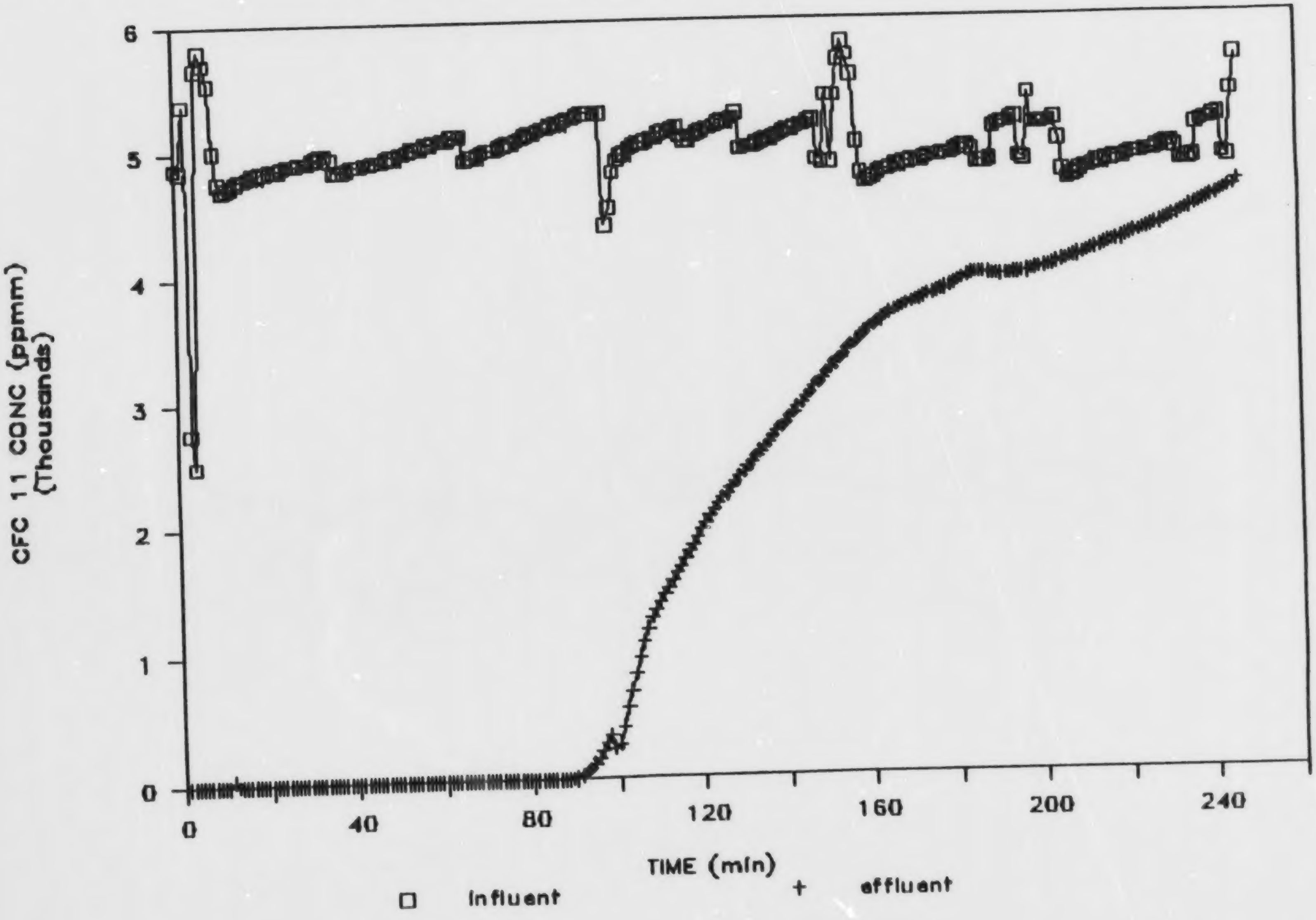
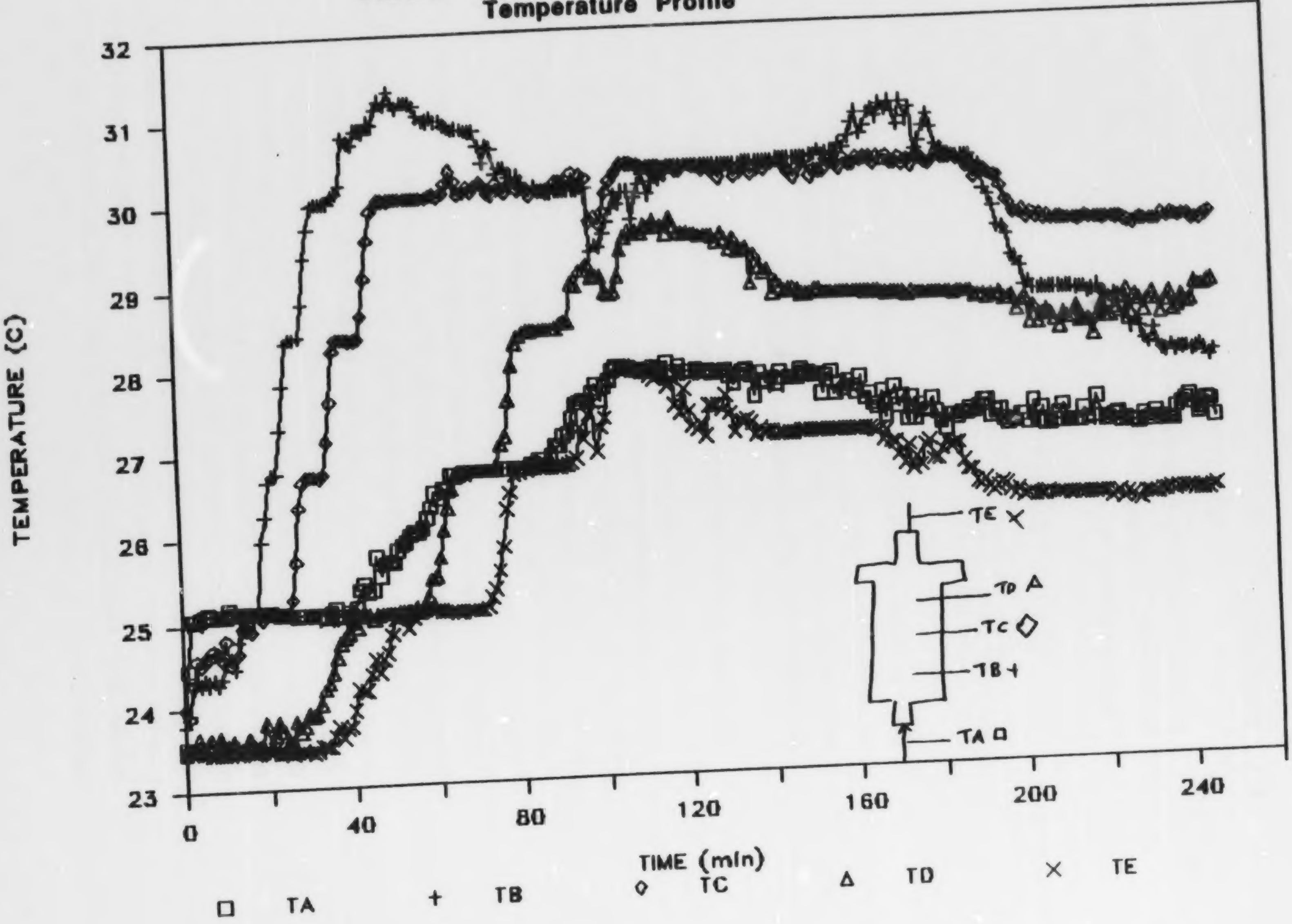


FIGURE 4.9 - CFC 11 Adsorption Test 7
Temperature Profile



4.2 Desorption

In order to reuse the canisters, the saturated adsorbent had to be regenerated or desorped. All desorptions were conducted in a Despatch Forced Air Oven at the following conditions:

- <50 L/min N_2/canister
- <500°C oven temperature
- <8 hour period
- Cold start (i.e. no heat up period)

Each canister was weighed before and after desorption and within the accuracy of the scale (± 0.1 g), all of the CFC adsorped was removed. In other words, it can be said that the proprietary adsorbent showed no evidence of any CFC residual whatsoever.

Desorption concentration and bed temperature profiles were measured on several specific cases. Unfortunately, since the adsorption tests were limited to 5,000 ppmv, we were unable to calibrate the instrument for the wide range of concentrations found during desorption (i.e. 0-100,000 ppmv). However, as a qualitative tool to monitor system trends, profiles were obtained for several CFC 113 desorptions. Figure 4.10 illustrates a typical desorption curve. The units on the ordinate axis are an uncalibrated measure of the concentration of CFC 113 in the effluent stream leaving the canister. It can be seen that the maximum concentration is reached by the first hour of desorption. This pattern was noted in every desorption. It can also be seen that, by the third hour, ~ 90% of the CFC 113 has been removed. The time for complete desorption is at least partly a function of the vapour pressure of the specific compound. Consequently, it is expected the CFC 12 will require a significantly shorter desorption time than CFC 113 for a given temperature. By comparison, the desorption for carbon is less parabolic (see Figure 4.11). It can also be seen that, in carbon regeneration, the concentration never reaches baseline again. This is indicative of the residual CFC.

A typical desorption temperature profile is presented in Figure 4.12. The internal thermocouples at 1/4 and 1/2 bed height take the longest time period to reach the plateau temperature. This is partly due to the significant cooling effect of the N_2 purge gas. The N_2 temperature has been observed to be as cool as 15°C.

FIGURE 4.10 - CFC 113 Desorption Test 1

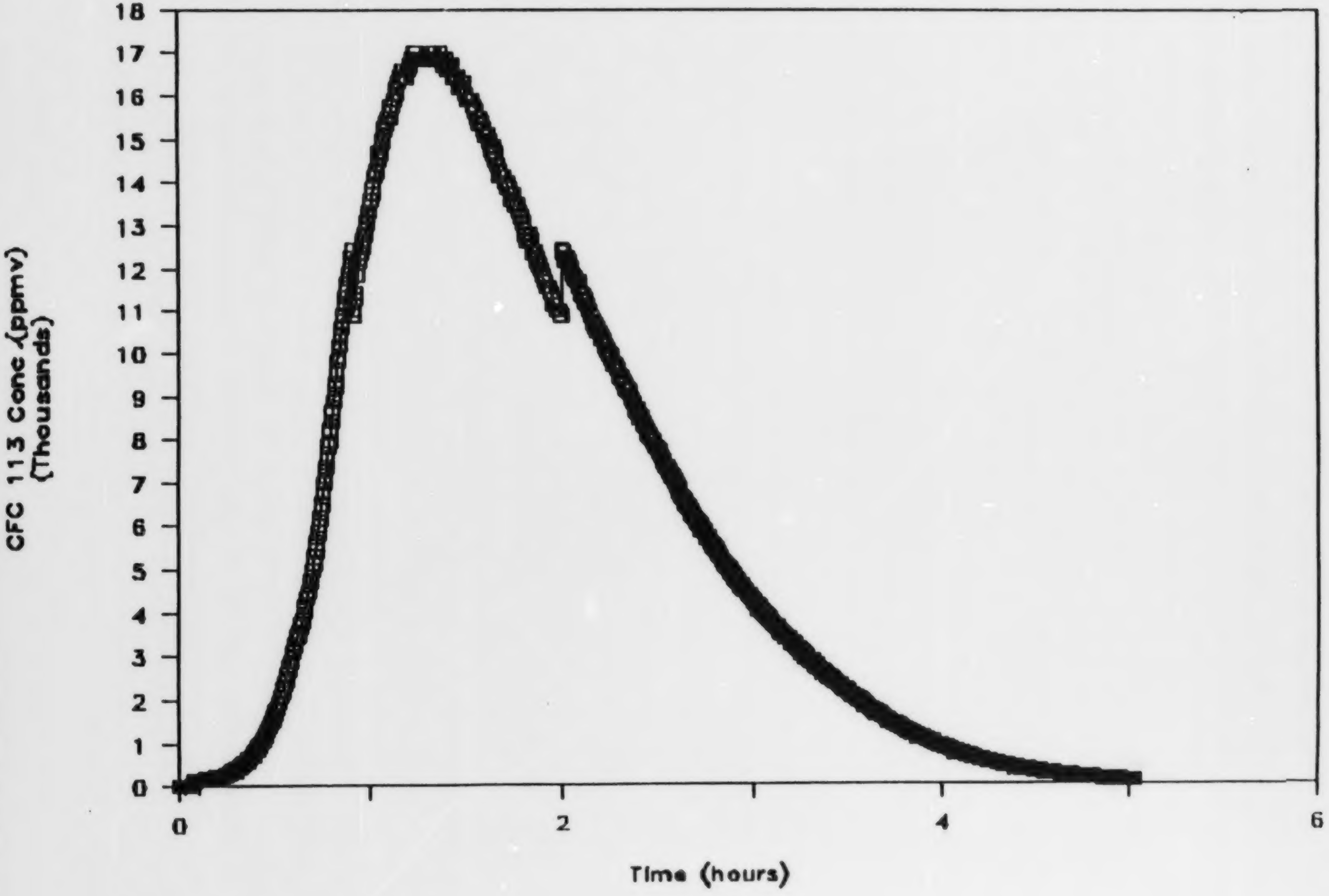


FIGURE 4.11 - CFC 113 Desorption Test 3, Carbon

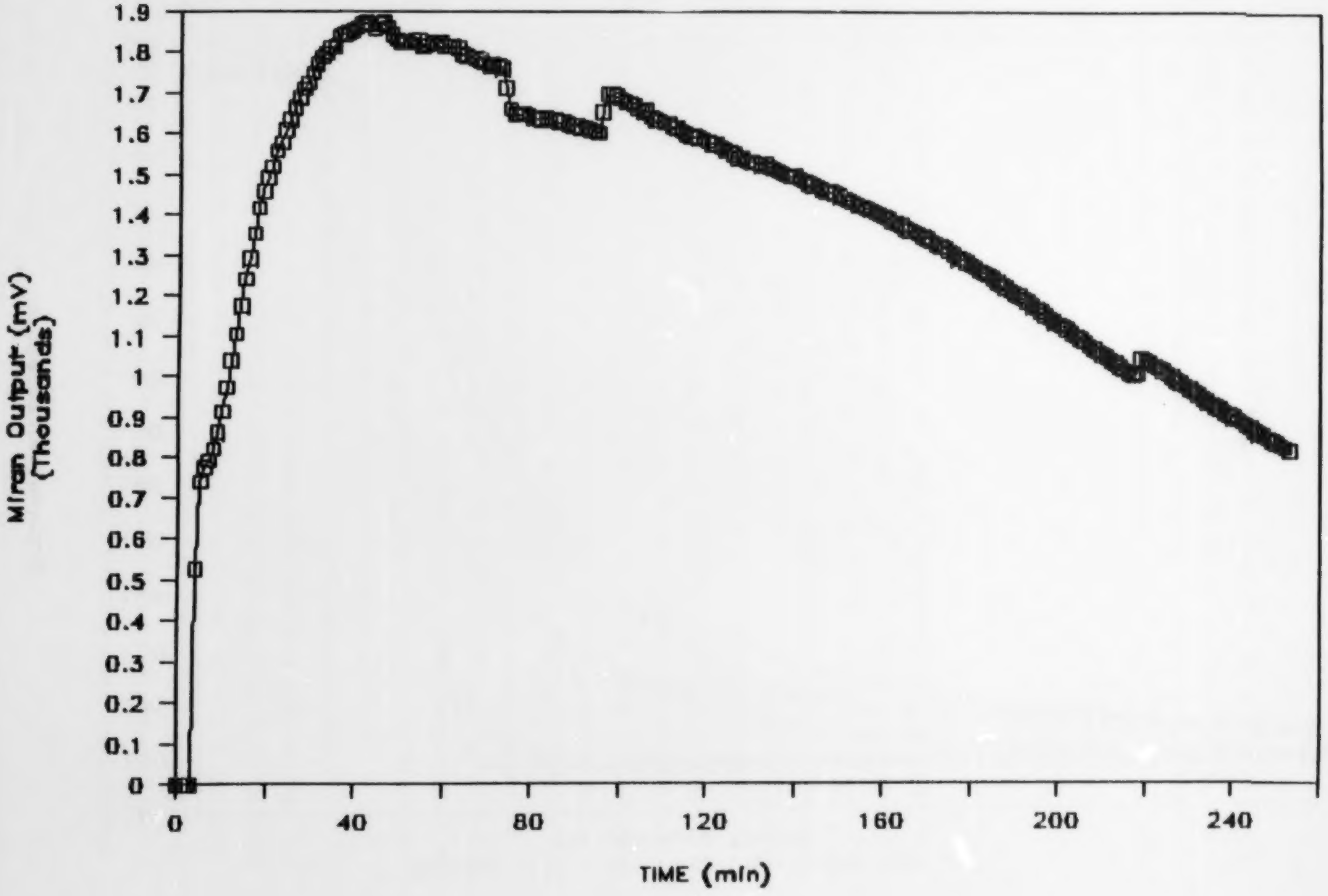
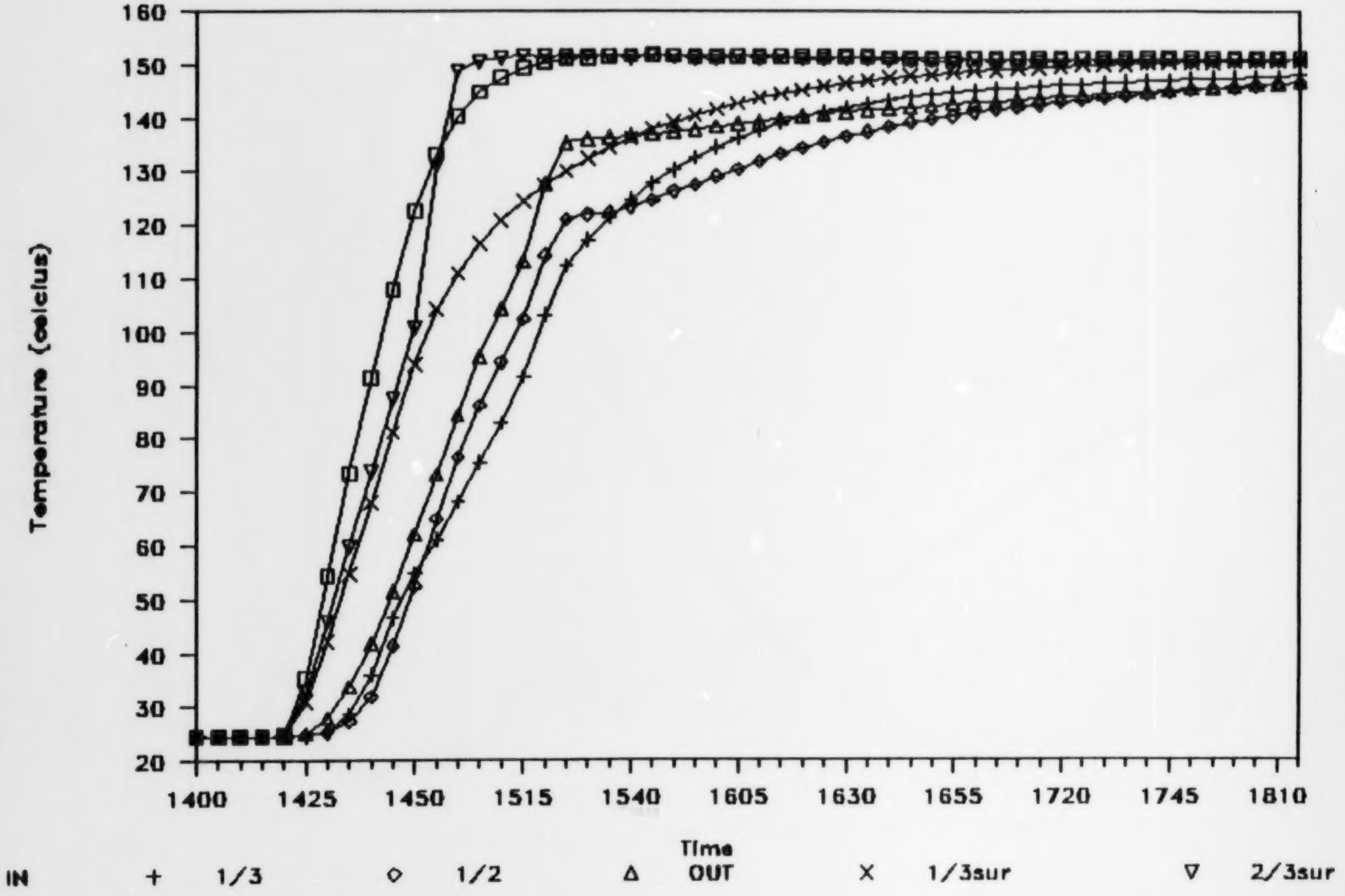


FIGURE 4.12 - CFC 113 Desorption Test 2
Temperature Profile



4.3 Recovery of the Desorped CFCs

A pilot plant was specified and assembled, such that the adsorped CFCs could be recovered during regeneration of the mol sieve. A schematic diagram of the recovery pilot plant is presented in Figure 4.13. The major equipment items used in the plant are:

(i) The desorption oven/canister manifold
(ii) The cryogenic chiller
(iii) The recovery vessel

The desorption oven was a 3.6 kW, 240 V, forced air oven that operated at < 500°C. The canister manifold was a 6 (or 12) way header with 1/2" 316 SS rigid or flexi tubing. The cryogenic chiller was supplied by Linde, McAdam Road, and consisted of a copper coil in a bath of boiling liquid nitrogen with an on-off temperature controller. The operating plan for the chiller was simply to control the level of liquid nitrogen in the vessel by an on-off solenoid valve. The solenoid valve was, in turn, controlled by an on-off temperature controller. This important feature allowed the chiller operating temperature to be varied, such that the wide variety of CFCs could be condensed with the same unit. Due to the relatively high vapour pressure of the CFCs, cryogenic condensation temperatures were required in order to achieve acceptable recoveries. Figures 4.14 to 4.17 present condensation efficiency curves for CFCs 11, 12 and 113, as well as HCFC 22, based on a 10% CFC concentration at the chiller inlet. These calculations were made by assuming Real Gas Ideality and Raoult's and Dalton's Law. The vapour pressure information was either obtained from DuPont or Matheson data or extrapolated from known vapour pressure/temperature relationships. The details of the calculations and the computer algorithm are presented in Appendix 8. From the curves, it can be seen that, for > 80% recovery, the condenser temperature must be controlled within close range of the freezing point, depending on the specific compound. However, if the condenser temperature were to exceed the freezing point, the solidified

CFC would obstruct the flow and eventually completely block the condenser coil, preventing any further recovery.

This phenomenon was experienced during commissioning of the pilot plant. The cryogenic chiller was unable to control the temperature sufficiently to achieve adequate CFC recoveries and avoid freezing and subsequent blockage in the coils. Several attempts were made to reposition the temperature sensor to attempt to overcome the problem. However, these met with no success. It was confirmed, by use of the Miran IR Analyzer on the condenser effluent, that, indeed, > 99% recovery was achieved before freeze-up. Unfortunately, once freezing occurred, the test had to be terminated. This operating difficulty made further CFC recovery testing impossible.

FIGURE 4.13 - CFC Recovery Pilot Plant

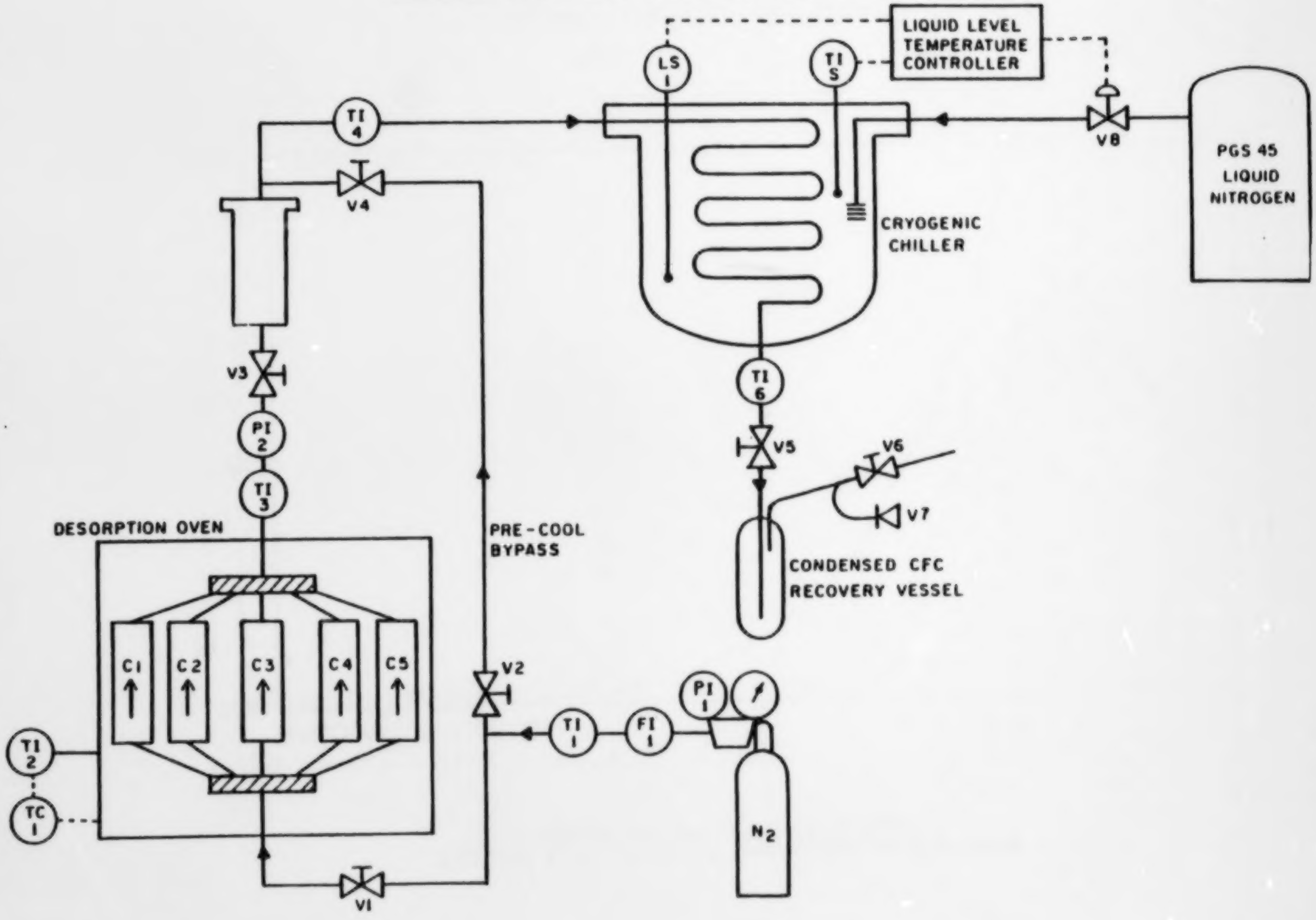

LIQUID LEVEL
TEMPERATURE
CONTROLLER
LS 1
TI S
TI 4
V4
V8
PGS 45
LIQUID
NITROGEN
CRYOGENIC
CHILLER
V3
PI 2
TI 3
TI 6
V5
V6
V7
DESORPTION OVEN
PRE-COOL
BYPASS
CONDENSED CFC
RECOVERY VESSEL
C1
C2
C3
C4
C5
V2
PI 1
TI 1
FI 1
TI 2
TC 1
N2
V1

FIGURE 4.14 - CFC 11 Condensation Efficiency
Based on 10% CFC 11 Influent

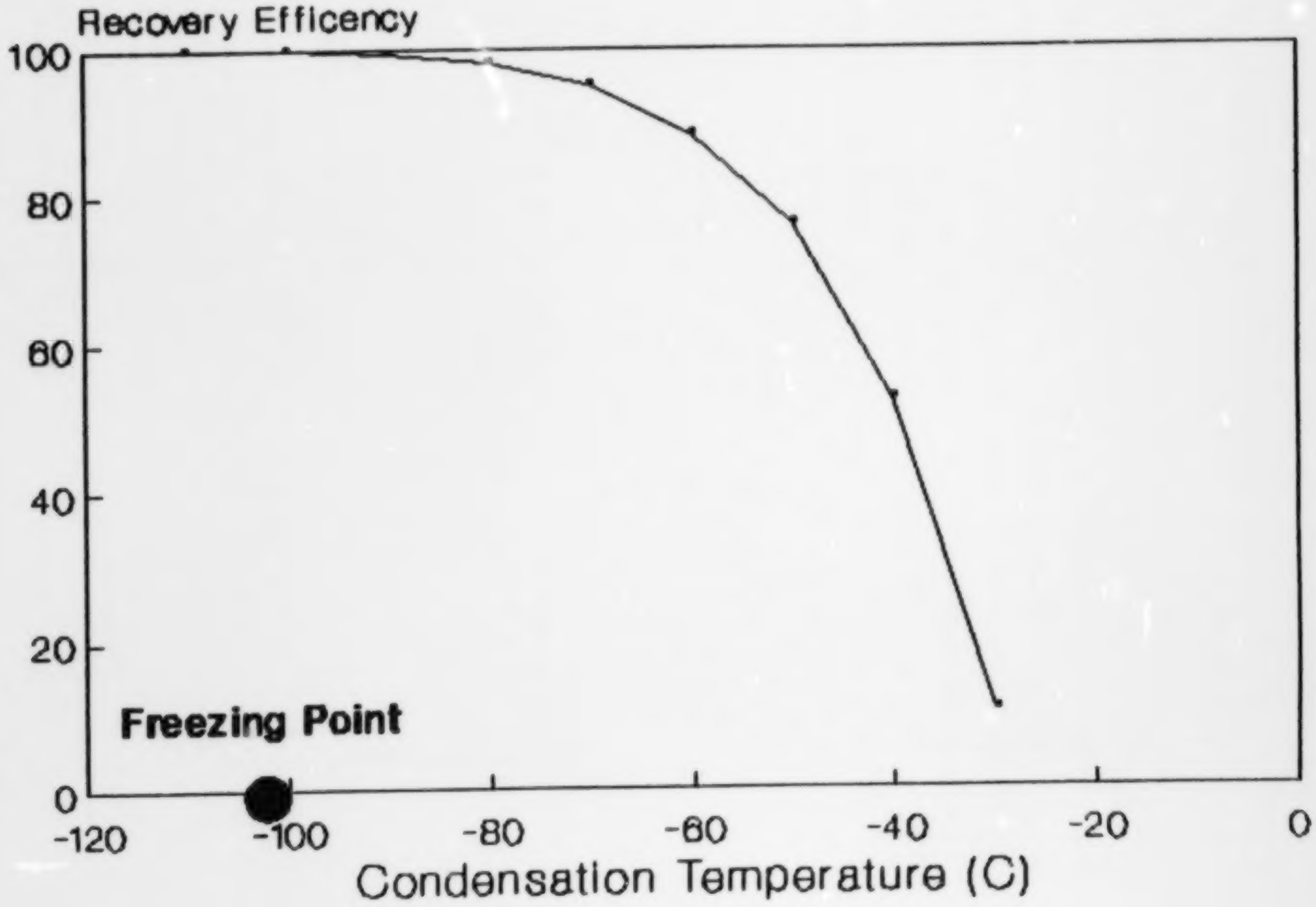


FIGURE 4.15 - CFC 12 Condensation Efficiency
Based on 10% CFC 12 Influent

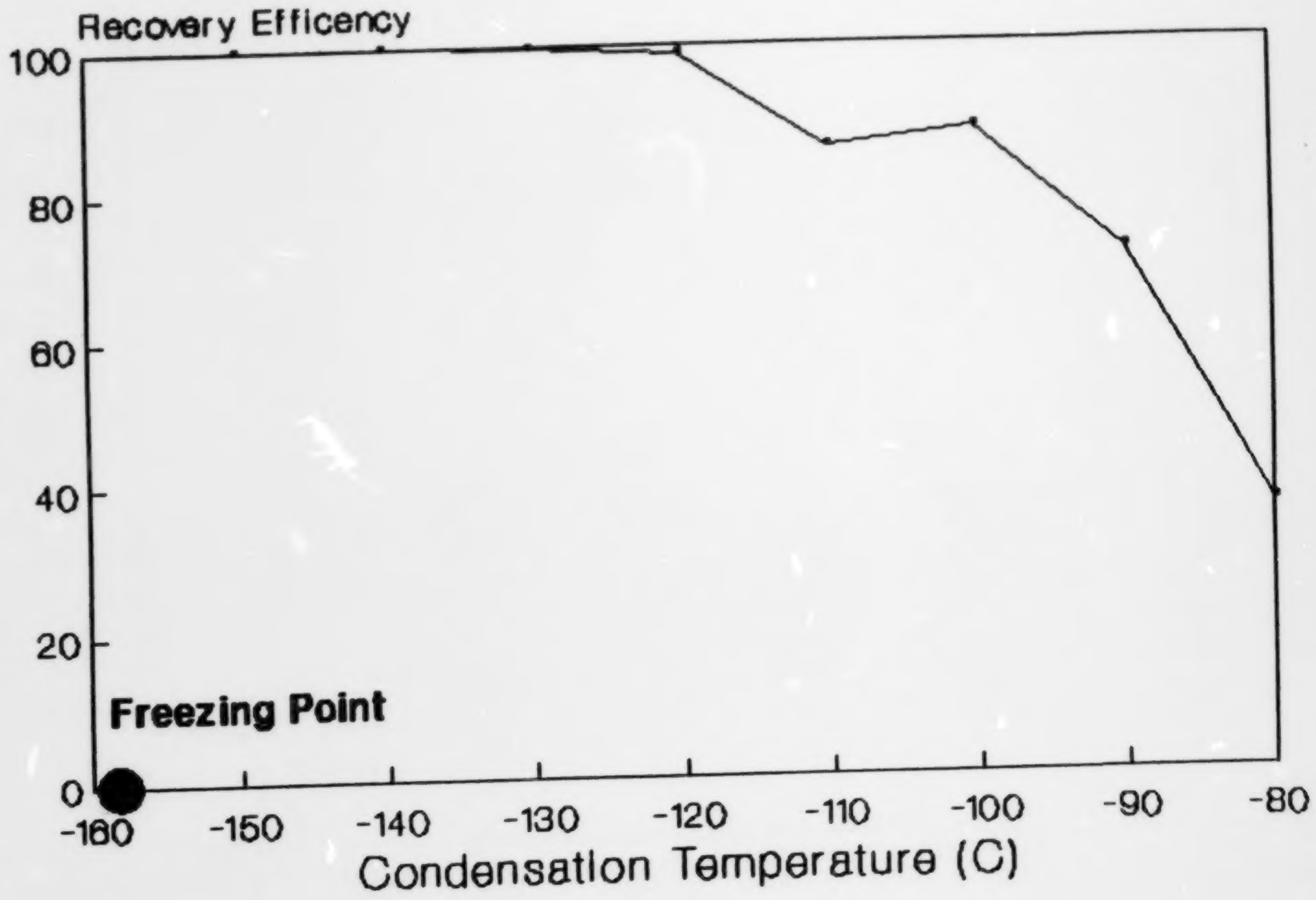


FIGURE 4.16 - CFC 113 Condensation Efficiency
Based on 10% CFC 113 Influent

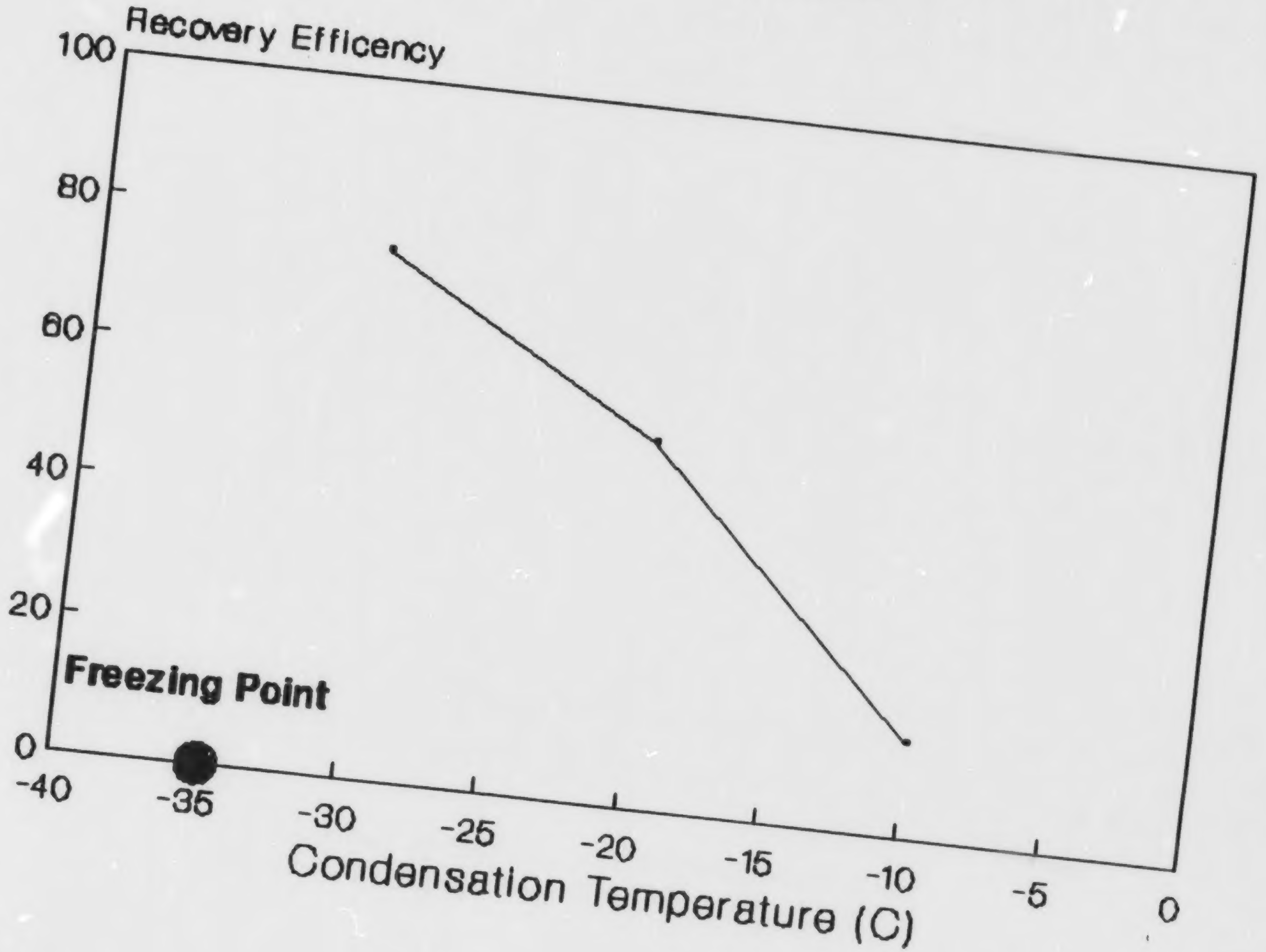
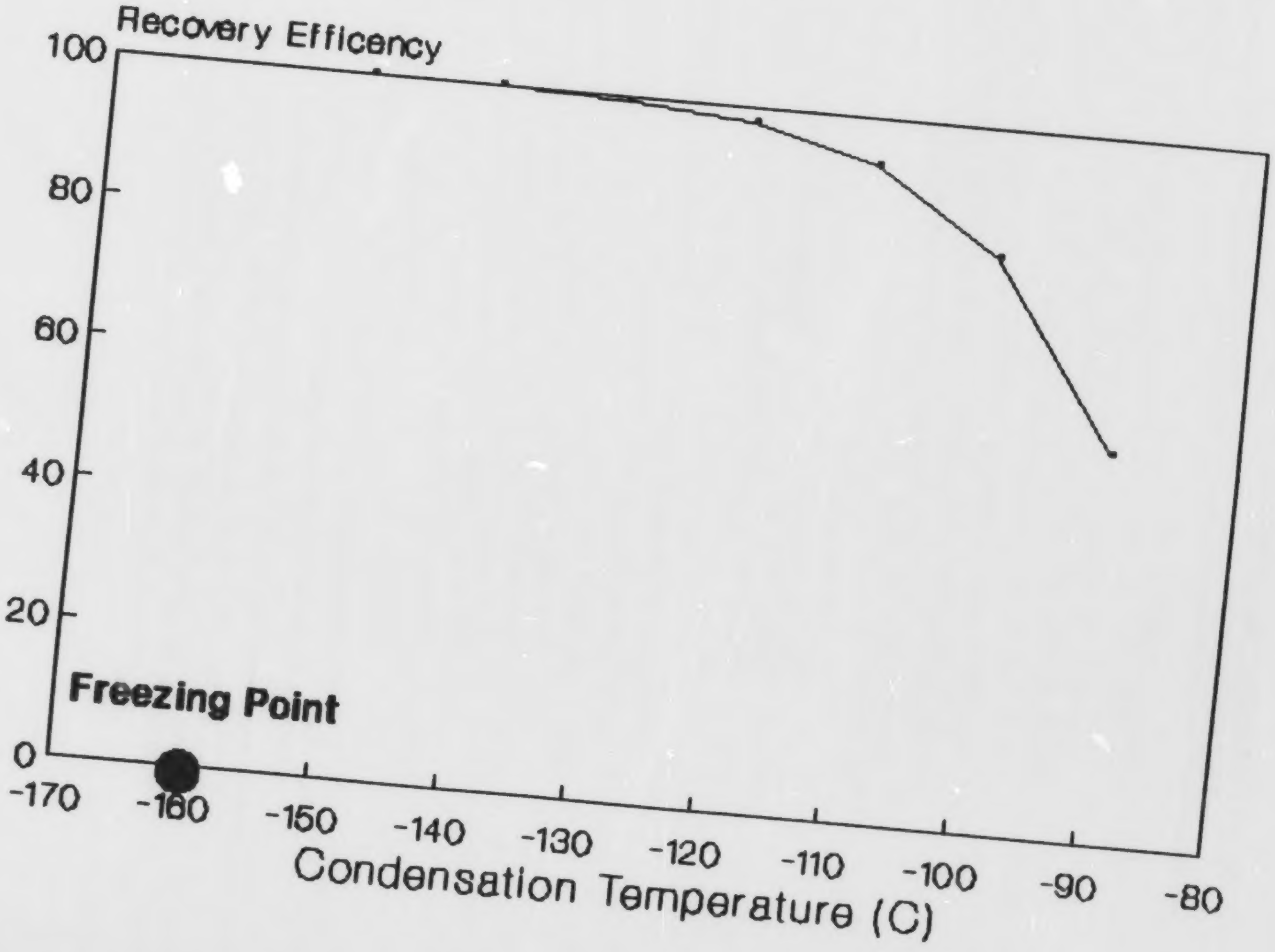


FIGURE 4.17 - HCFC 22 Condensation Efficiency
Based on 10% HCFC 22 Influent



5. COMMERCIAL OPPORTUNITIES FOR THE LINDE TECHNOLOGY

5.1 Introduction

In this section, the information developed in the surveys and visits (Section 2) is combined with the testing in Section 4 to evaluate the commercial opportunities for the Linde technology. For each potential area, i.e. domestic refrigeration, flexible foam, etc., applicability to four potential sources of CFC emissions are considered, viz.:

- During manufacture
- During servicing of equipment
- Leaks from equipment or emissions in use of CFCs
- During scrapping of equipment.

Where the information exists, the following points are covered on each of the potential sources of CFC emissions:

- Quantity estimate on CFC emissions and quantity recoverable
- Potential method of applying the mol sieve technology
- Appropriateness of competitors' technology
- Value to Linde in recovered CFC and market for technology
- Reasons for the value judgement

It was not possible to develop all of this information in all instances, but as much as possible is included.

The result of this analysis is presented in Table 5.1, which summarizes an opportunity as being good, fair or poor

TABLE 5.1 - OPPORTUNITIES FOR THE LINDE TECHNOLOGY

			CFC Emissions		
Application	Recoverable Item	Manufacture	Service	Leaks (or in use emissions)	Scrap
Commercial Refrigeration/Air Conditioning	CFC 12 HCFC 22	Fair-Good	Fair-Good	Difficult but could be good	Good*
Domestic Refrigeration/ Air Conditioning	CFC 12 CFC 11	Poor-Fair Good	Good	Poor-Fair	Good Good
Mobile A.C.	CFC 12	Poor	Poor-Fair	Poor	Good*
Rigid Packaging	HCFC 22	Good			Poor-Fair
Rigid Foam	CFC 11	Good			Good
Flex. Foam	CFC 11	Good			N/A
Solvents	CFC 113			Good	Poor
Portable Fire Extinguishers	Halon 1211		Fair	Poor	Good*
Flooding Fire Extinguishers	Halon 1301		Poor-Fair	Good	Good*
Sterilant Gases	CFC 12/Eto			Good	
Aerosols					Good but limited

*These are good opportunities for CFC recovery but may not require the adsorption technology. All will, however, require a good infrastructure for collection, purification and redistribution of CFCs. Linde could consider undertaking this as an adjunct to the Blue Bottle™ service infrastructure.

5.2 Commercial Refrigeration & Air Conditioning Services and Installation

Estimates from Environment Canada 1987 gave 3,604 tonnes/year as CFC used in the commercial refrigeration and air conditioning sector for service and installation. This includes:

1. retail refrigeration units, which are CFC 12 and 502 predominantly;
2. cold storage/food processing, which are 12, 22 and 502;
3. industrial refrigeration, which are 12 and NH_3;
4. transportation refrigeration, which are predominantly CFC 12;
5. comfort air conditioning units which can be divided into two sections:
   - (i) unitary systems, where 22 is mostly used with some older systems using 12, and
   - (ii) water chilling systems which comprise the positive displacement system using almost exclusively 22 and centrifugal chillers which use CFC 11, 12 primarily.

Although exact numbers are not available, taking estimates of CFC discharge figures from the UNEP report as they relate to the retail refrigeration areas, the following percentage losses occurred in industry in 1987:

Manufacturing Leak Testing	2%
Installation	3%
Leakage	45%
Service	10%
Disposal	40%

Using these figures as rough guides to predict areas where UCCL systems might apply, the following quantities may be recoverable:

Manufacturing Leak Testing	72 tonnes
Installation	108 tonnes
Leakage	(1622)
Service	360
Disposal	(1442) - est as banked in original installation

5.2.1 Commercial Refrigeration and Air Conditioning

Manufacture

In the manufacturing area, many industries have gone away from using CFC to test equipment. Of those that are continuing with this practice, many have already purchased units to recover their CFCs. Of the remaining companies, some use a combination of CFC with an inert gas. These diluted CFC streams may be good candidates for recovery via the Blue Bottle™ system. This sector may contribute up to 70 tonnes/year, although this figure will likely decline yearly. Taking an estimated 25% of 70 tonnes/year eligible for recovery yields approximately 17.5 tonnes of CFC. At $4/lb, the recovered CFC value could be approximately $154,000.

Installation of refrigeration systems have required removal of moisture in the past by flushing with CFCs. Although the practice is continuing to some degree, many have adopted the suggestion of the Code of Practice and substituted other gases. Gross estimates of 100 tonnes/year emitted from this practice for the 1987 generation values are most likely exaggerated. Assuming 25% of installations are still carried out in this manner, 25 tonnes of CFC may be recovered at a value of $220,000.

This sector does have potential to use Blue Bottle™ or capture technology, although the industry trend is to not emit CFC during these routine practices. The rating for the sector is fair to good, depending on the adoption of the Code of Practice guidelines.

Rating: ***Fair to Good***

Servicing

Servicing of units in the past has involved discharge of CFCs in the purge lines, in areas where isolation is sought and in start-up of the system with new CFCs. Other areas of interest to service persons could be the clean-out of Vampire equipment utilized to capture large quantities of CFC pumped out of a system. When Vampire units are utilized for different types of CFCs, these recovery units must be pumped out to rinse out residual gas before new CFCs are introduced. An estimate of 10% of the total CFC used in commercial refrigeration and air conditioning could be lost in this manner, resulting in approximately 360 tonnes of CFC. Blue Bottles™ similar to those used by domestic refrigerator repairmen could be utilized with an estimated 20 trips/year. Assuming 25% of this is actually recoverable utilizing the Blue Bottle™, the type and, therefore, value of CFC/HCFC would vary and collection mechanisms for mixed CFC would have to be worked out. The rating for this sector is, therefore, fair to good.

Rating: ***Fair to Good***

Leaks

Leaks of CFCs from systems comprise close to 50% of CFC usage in this sector. With numerous older models still in service, the loss may continue until strictly prohibited. An opportunity exists here only if suitable detection of leaks is possible and exhausts can be routed through Blue Bottle™ beds. Standby systems at purge outlets may be an option for only a few companies due to the costs unless regulations are changed. Other technologies that may be competitive in this application would be carbon adsorption. The quantity of CFC that could potentially be recovered is upward of 1,600 tonnes. This figure may be adjusted if faulty equipment is phased out.

The potential for Blue Bottle™ technology in this application is difficult and requires great motivation, probably from regulations, to implement. Rating for this application is difficult, but could be good, as no other technologies have been seen to be successful at this time.

Rating: ***Difficult but could be Good***

Scrap

Units that are no longer required will need to be discharged of remaining CFCs according to the Draft Code of Practice. This may be a large potential market to recover used CFCs where reintroduction of the gas is not required. Adsorption may not be necessary, but further purification of the material may be required.

Scrap materials from commercial sources are generally picked up by scrap metal dealers or are taken out of service during retrofitting and could be taken back to HVAC shops. HVAC shops could likely have their own Vampire recovery unit which they use in the field, but many scrap metal recovery companies are not interested in CFC recovery opportunities. It may, therefore, be a good business opportunity for Linde to offer this as a service to scrap dealers, either on a standby unit which could be easy to use at the site by the scrap dealers, or a mobile operation which could move from site to site on demand. The estimated potential of banked CFC quantities in commercial refrigeration and air conditioning equipment is 40% or approximately 1,400 tonnes. Assuming 80% of units have CFC remaining in them, Linde may be able to capture 50% of market, or 560 tonnes. Other technologies to recover CFC from scrapped goods, such as various Vampire units, do exist, although these would ordinarily require some further purification. The potential value of CFC recovered at 50% market share would be close to $5 million.

The rating for Linde involvement in this sector is good and could involve a combination of Blue Bottle™ and Vampire technologies, along with the required infrastructure for either mobile or stationary capture technologies. .

Rating: ***Good***

5.3 Domestic Refrigeration and Air Conditioning

5.3.1 Manufacture

This sector uses approximately 200 tonnes/year of CFC 12 and HCFC 22, of which about 2-10 tonnes might be emitted. The Blue Bottle™ might be applied to remove CFC from appliances that leak during manufacture, but the vampire technology is very appropriate here, as the clean CFC can be removed and re-installed when the leak is fixed. The value of CFC recovered at $4/lb would be $17,600-$88,000. Because the vampire unit can readily be used in a factory situation and the recovered CFC reintroduced right on the spot, this is not considered a likely market for the Blue Bottle™ technology.

Rating: ***Poor***

5.3.2 Servicing

Environment Canada estimates that 68 tonnes/year of CFC 12 is used for servicing domestic refrigerators. About 20-25%, or 15 tonnes, is to replace material that has leaked. Indications from the survey are that the level used specifically for domestic refrigerator servicing when CFC has to be withdrawn would be 10-20 tonnes/year, i.e. 40-80,000 service calls per year to service refrigerators; AHAM sources estimate 4-5 tonnes/year. Extra CFC 12 use is probably taken up in sweep charges and equipment blowouts.

The vampire units are cumbersome to take into houses to service refrigerators and do not perform well on low volumes of materials. For central air conditioning, the vampire units may be more appropriate. The units are larger and can often be accessed from outside.

Value of CFC potentially recoverable from domestic refrigeration at $4/lb is about $88,000-$176,000/year. For all domestic cooling, assuming 50% for the Linde technology, would be $233,000. This is considered a good prospect for the Linde technology because of the convenience and portability of the units. Strong regulations would be required to enforce use of any system.

Rating: Good

5.3.3 Leaks

About 15 tonnes/year is estimated to leak from cooling equipment in use. Most of this is unavailable. Possibly, we could think of incorporating a Blue Bottle™ bed around the devise to capture leaking CFCs, but this is considered unlikely.

Rating: Poor

5.3.4 Scrapping of Refrigerators and Air Conditioners

It is estimated that about 100-150 tonnes/year of refrigerant CFC 12 would be associated with domestic appliances being scrapped. 400-500 tonnes/year of CFC 11 in the foamed insulation associated with scrapped appliances would also be potentially available. The quantity recoverable would depend very much on the infrastructure in place to collect these appliances and the strength of regulations requiring removal of CFC prior to disposal and the CFC quantity remaining in the units.

The Blue Bottle™ technology could be applied in fairly large beds being used in scrapyards, loaded and taken back to Linde for regeneration. This would probably be more economical than individual blue bottles.

Vampire units are appropriate for the removal of CFC, but, in this case, the recovered CFC has no immediate use so that an infrastructure to collect, purify and redistribute the CFC would be required. Linde might consider a combination of activities in this market place. The provision of a comprehensive service to decommission scrapped appliances containing CFC would also be a safer route because the quantity recoverable could be variable.

The potential value, if all of the refrigerant were to be recovered, would be $1.32 million. The rating is good either for Blue Bottle™ technology or provision of service to purify and reclaim Vampire recovered refrigerants.

Rating: ***Good***

For the CFC 11 contained in the foam, the mol sieve technology would be most appropriate, when combined with a plastics reclamation facility. The scrap polyurethane could be hydrolyzed to recover polyols and CFC 11 emitted during hydrolysis in an enclosed area captured on a bed of molecular sieve which could be regenerated in place or changed and shipped to Linde for regeneration. The Vampire units have no role in this application.

Potential value of CFC recovered, assuming $4/lb for CFC 11, would be $3.5 million-4.4 million; depending upon whether in-house regeneration is used or whether material is shipped back to Linde.

Rating for this application is good. It is more complicated as it combines recycling of plastics with the recovery of CFC, but this is a potentially exciting new opportunity.

Rating: ***Good***

5.4 Mobile Air Conditioning

5.4.1 Manufacture

Environment Canada estimates that, in 1987, 2,100 tonnes of CFC 12 were used in Canada to manufacture mobile air conditioners. Of this, 950 tonnes went into cars and trucks destined for the domestic Canadian market. If a proportion of units which leak after manufacture is similar to domestic refrigerators, i.e. 1%, the potential for recovery would be about 10 tonnes/year.

It is felt that Vampire units are better suited to draining these leaking units and re-installing the refrigerant when the leaks are repaired. Rating for this application is poor because competitive technology is likely to be less expensive and can be appropriately applied.

Rating: Poor

5.4.2 Servicing

Environment Canada estimates that 800 tonnes/year of CFC 12 are used to service mobile air conditioners. An estimate of 50% of this is used to replace CFC which leaks in use and 50% to replace CFC extracted by service technicians prior to servicing units. Thus, the potential for the Linde technology is 400 tonnes/year.

The Blue Bottle™ technology would be applied using quite large vessels, maybe two sizes of 100 lbs and 500 lbs, which could be used to service 10 or 50 cars.

As in the manufacture of mobile air conditioning, the Vampire technology is quite appropriate for this application. Cars are serviced at service stations, so fixed Vampire units can be used. The removed CFC can be re-installed after servicing so there is no problem of what to do with recovered CFC. The potential value of CFC recovered is $3.5 million.

Because of the way in which cars are serviced and the applicability of the Vampire units, this application is rated as poor to fair.

Rating: ***Poor to Fair***

5.4.3 Leaks

The amount of CFC estimated to leak in service is 400 tonnes/year. It is difficult to envision any control technology that could be effectively applied to controlling leaks from mobile air conditioners.

A more realistic approach to this would be to try to improve the mobile air conditioning systems to reduce leakage through coupling design, etc. It might be feasible to consider installing some kind of enclosure with a mol sieve bed to be on standby to capture leaks, but the costs would be quite high. This is impractical as the costs would be extremely high. The rating for this opportunity is poor because of the practical limitations to applying the technology.

Rating: ***Poor***

5.4.4 Scrap

Cars are typically scrapped after about 8-10 years. On the assumption that, in 1982, the amount of CFCs used for domestic car and truck production was in the order of 700-800 tonnes and, again assuming 50% have leaked in service, the amount of CFCs in scrapped cars might be 350-400 tonnes.

These are dealt with through a series of automobile wreckers and dismantlers and a much smaller number of major scrapyards. The dismantlers reclaim usable parts prior to shipping hulks to a major facility capable of shredding and baling scrap steel. CFCs recovery would probably have to be achieved by the dismantlers as, by the time the hulks reach the major yards like Intermetco, the air conditioning lines and compressor would be broken.

This could be a very good opportunity for the Blue Bottle™ or the Blue Tank! There would be less interest in using the Vampire units to extract and purify, as there is no demand to replace the CFCs as there is during servicing. Capture and compression of CFC 12 will result in a high pressure reclaimed material which must be shipped elsewhere for purification.

The concept of an ambient pressure adsorbent might be attractive. It is very easy to use and Linde could provide large units, perhaps mobile, which Linde would pick up and exchange on a regular basis. However, both approaches have the potential to service this market.

Value of CFC recovered would be $3.1-33.5 million.

It is unlikely that the Linde technology would be used by all scrapyards, so appropriate market proportion estimates should be applied. Like many of the applications discussed, it will still require legislation to ensure that CFCs are recovered from the scrapping of automobiles. Even if the Vampire technology is applied, an infrastructure to collect, purify and redistribute the CFCs is required.

The rating for this application as a commercial opportunity for Linde is good, either for the Linde technology or to be involved in the infrastructure for recycling of material captured by the Vampires.

Rating: ***Good***

5.5 Rigid Packaging

5.5.1 Manufacture

CFCs have been used as blowing agents in rigid foam for packaging items such as egg cartons, meat trays and dunnage (i.e. peanut packing chips). The quantity of CFC 12 used in this sector in 1987 is an estimated 1,840 tonnes. Most Canadian manufacturers have moved or will soon move away from CFC use in these items and replace it, most likely, with HCFC 22. Much of the CFC (approximately 70%) is actually lost in the manufacturing process. Assuming HCFC 22 can replace CFC 12 pound per pound, capture of HCFC 22 could produce an estimated $12 million market for prompt recovery.

Alternative capture technologies at this time are carbon adsorption, which, we feel, is inferior to the Blue Bottle™ for this application. The rating for this sector is, therefore, good.

Rating Good

5.5.2 Service

Not applicable

5.5.3 Leaks

Not applicable

5.5.4 Scrap

Collection of scrap polystyrene packaging wastes is occurring for purposes of recycling the plastic components. Companies who shred the polystyrene for reprocessing will probably not emit the CFC or HCFC, as previous studies from Sweden have shown(43). Unless further processing, i.e. hydrolysis, is carried out with the scrap, capture of CFC or HCFC at these facilities will not likely be possible. The rating for this sector is, therefore, poor to fair.

Rating ***Poor to Fair***

5.6 Rigid Foam Insulation

5.6.1 Manufacture

The rigid foam insulation sector uses 5,700 tonnes of CFC 11 per year (1987) as estimated by Environment Canada. CFCs are used as a blowing agent in rigid polystyrene, polyurethane and phenolic foam insulation, such as found in buildings, tanks, pipes, refrigerators, etc. Most of the CFCs are retained in the closed cells of the foam and estimates of loss during manufacture vary slightly with each sector.

Polyurethane insulation of refrigerators and freezers are an estimated 800-1,000 tonnes per year (est. from UNEP reports taking 10% of U.S. production). 0-15% may be lost in manufacturing, resulting in a potential up to 150 tonnes per year of emissions that could be recaptured. On-site licensing may be expensive for the relatively small amount lost per individual company, although processes may be easily adapted for capture via molecular sieve adsorption. Competitive technologies such as carbon adsorption are being studied at the pilot scale. Some reduction of emissions is possible with better controls, but manufacturers are wary of using blowing agents that do not provide the same insulation value. An estimate of the value of recovered CFC at $4/lb is about $13 million.

Boardstock which also uses CFC 11 consumes an estimated 2,200 tonnes per year (UNEP from U.S. production estimate). 5-10% is estimated to be emitted from manufacture, therefore leaving a maximum of 220 tonnes per year as emissions on site. Recovered CFC could be valued at up to $2 million.

Polyurethane spray, applied or poured in place during manufacturing consumes an estimated 2,000 tonnes per year with emissions at 5-10%, resulting in an estimated 200 tonnes per year as quantity of CFC escaping. Much of this material is sprayed in place and, therefore, not suitable for capture technologies as we know them.

Polystyrene building insulation boards use CFC 12 as the most common blowing agent, although many have already adopted HCFC 22 and industry representatives were not eager to share data.

This sector, in general, looks promising for mol sieve technology. The characteristics of blowing agents used in insulation foam production will require high value material which would merit recapture, or because VOC emission levels dictate its capture.

Rating: Good

5.6.2 Service

Not applicable

5.6.3 Leaks in Service

Not applicable

5.6.4 Scrap

Capture of CFCs from scrap insulation from both domestic and commercial sources may be a large source of CFCs as more than 80% of the CFCs stay with the foam. Hydrolysis of the plastic and subsequent capture of polyols and CFC 11 emitted in an enclosed area on a bed of proprietary molecular sieve may be possible The only competitive technology to date is carbon adsorption. The infrastructure to recycle building and construction waste may become more available as municipalities are starting to prohibit the landfill of various materials. The actual quantity that could be captured depends on these regulatory incentives. The prospect for Linde technology in this component is good.

Rating: ***Good***

5.7 Flexible Foam

5.7.1 Manufacture

Environment Canada estimates that 1,450 tonnes of CFC, mainly CFC 11, is used for the manufacture of flexible foam products. There is a concerted effort to reduce the use of CFC 11 wherever possible, and projections of 80% substitution have been suggested. Water substitution in the automotive industry may have the greatest potential (i.e. 644 tonnes/yr consumption in 1987). The substitutes being proposed include water, HCFC 22 and others, and methylene chloride. All of the blowing agent is lost during the manufacture and curing of this open cell product, as well as some quantities of isocyanates and polyols. It is unlikely, in the long term, that flexible foam manufacturers will be allowed to continue emitting these volatile organic compounds (VOCs) so, even if CFCs are reduced, there will be, we believe, a need for an effective control and recovery technology.

Evidence from Europe(46), where they have applied activated carbon adsorption technology to control CFC 11, has shown that, even with the polymeric chemicals in the exhaust, there has been no fouling of the adsorbent after 7 months and 50 cycles.

One of the difficulties of applying the mol sieve adsorbent technology, or any adsorbent technology, is the very high air exhaust rates used to protect workers from the toxic chemicals used in the process. The European experience has shown that these rates can be substantially reduced by some system redesign while still ensuring protection for the plant workers.

The design of the adsorption system would require imaginative engineering, but the only competitive technology for this application, carbon adsorption, would also require the same careful design to ensure reasonable adsorption costs.

There are seven flexible foam manufacturers in Canada and, so, each would have fairly substantial emissions of VOCs and would best be serviced by on-site adsorption and regeneration systems.

The potential value of captured CFC is $12.8 million/year.

Rating for this application is good, provided there is a regulation of VOC emissions. We believe that the technology can achieve a more complete removal of VOCs from the air stream being emitted during flexible foam manufacture than other adsorbents such as carbon. Also, more complete regeneration of the adsorbent can be achieved with less breakdown of desorbed species.

Rating: ***Good***

5.7.2 Service

Not applicable.

5.7.3 Leaks in Service

Not applicable.

5.7.4 Scrap

Not applicable.

5.8 Solvents

5.8.1 Manufacture

Not applicable.

5.8.2 Service

Not applicable.

5.8.3 Leaks or Emissions During Use

The CFC emissions of solvent CFC 113 are almost exclusively associated with losses from degreasing operations.

Environment Canada's estimate for 1987 of the volume of replacement CFC for solvent degreasing was 1,900 tonnes/year. Since this is calculated from the replacement of CFCs lost, it does not account for the volumes of CFCs being controlled by some large users such as IBM and Northern Telecom, using carbon adsorption systems. We estimate that the amount controlled could be at least as big as the amount emitted, so the total potential emissions to be controlled would be about 4,000 tonnes/year.

Application of the Blue Bottle™ technology in this area would involve on-site adsorption/regeneration for larger emission sources, but might involve on-site adsorption with off-site regeneration for very small sources. Since CFC 113 is a liquid at ambient temperatures, the complexity of the regeneration system is much less than for those CFCs that are gases at ambient conditions. So, even for quite modest emission sources, on-site regeneration may be economically feasible. Vampire systems are not applicable for the recovery of CFCs from dilute streams of this nature. The competitive technology would be carbon adsorption. We believe the Linde technology can achieve complete removal of CFC from emission sources and more effective and complete regeneration of the adsorbent and less breakdown of recovered CFC.

The other major competitor in this section is the move to other methods of degreasing using aqueous systems and alternative fluxing agents to eliminate the need for degreasing. Some discussion of these directions are included in the sections of Section 2 and in the Appendix dealing with Northern Telecom.

The value of CFCs potentially recoverable, based on 1987 estimates, ranges from $16.7-35.2 million, based on $4/lb for CFC.

Our rating for this as a commercial opportunity is good. This is based on it probably being economic to consider recovery based on the value of recovered CFCs and on our belief that the process allows more complete capture of CFC from emission sources.

Rating: ***Good***

5.8.4 Scrap

For companies going away from solvent degreasing using CFC 113, there are already outlets for surplus contaminated CFC 113 for recycling. On an ongoing basis, sludge is removed from degreasing tanks and sent for recovery. This infrastructure is already in place and does not provide an attractive commercial opportunity for Linde. Our rating of this, therefore is poor.

Rating: ***Poor***

5.9 Portable Fire Extinguishers

5.9.1 Manufacture

Not applicable.

5.9.2 Service

Losses of Halon 1211 from the servicing of portable fire extinguishers are estimated to be 13.5 tonnes/year. This may be an area for application of the Blue Bottle™ during service calls or for a larger adsorbent bed for in-shop servicing of fire extinguishers. It should be noted that halons were not tested in the experimental program. Application of the technology would not be as simple as with domestic refrigeration, as the adsorbent canister cannot be directly connected to the fire extinguisher. Some sort of hooding and capture device would have to be developed.

Vampire units are not applicable in this case. Carbon could possibly be used, but, as discussed in other applications, the proprietary molecular sieve has superior adsorbent properties.

The value of the recovered Halon, assuming a $6/lb value, would be $178,000. We have rated this opportunity as fair. The Linde technology would work, but it might be quite difficult to apply. Strong regulating requirements would have to be in place to make this opportunity more attractive.

Rating: ***Fair***

5.9.3 Leaks and In-Use Emissions

It is estimated that about 45 tonnes of Halon 1211 is emitted annually in fighting fires. This would be extremely difficult to control, as this is the primary purpose of having the portable fire extinguisher. Another 27 tonnes is estimated to be emitted during testing and training. Certainly, for training, this practice would be banned, and surrogate chemicals used in special training extinguishers. Testing of portable fire extinguishers may also be a practice that may be banned or could be subject to control using a similar system to one developed for the service of these units. About 4.5 tonnes are estimated to be discharged through leaks and other unwanted discharges. It is almost impossible to envision how these could be controlled. As a unit required in emergency, a portable fire extinguisher cannot be enclosed as that defeats the purpose of having it readily available.

We believe that the opportunity in this case should be rated as poor.

Rating: ***Poor***

5.9.4 Scrap

From UNEP data, we believe that as much as 3,000 tonnes of Halon 1211 may be banked in portable fire extinguishers in Canada. Scrapping of old or defective units could be an interesting market for Linde. If 10% of the existing units were taken out of service each year, the potentially recoverable Halon 1211 would be 300 tonnes/year. At a value of $6/lb, the value of this recovered Halon would be nearly $4 million.

It would not necessarily require the adsorption technology, except to control emissions from a simple draining of the scrapped units. The metal and plastic components of the out-of-service extinguisher could also be separated for recycle. The in-house emission control system would be based on the Linde adsorption technology. No producer of Halons exists in Canada. In other jurisdictions where the Halons are manufactured, this role might be assumed by the manufacturer.

We believe that this opportunity should be rated as a good one for Linde. While it makes limited use of the adsorption technology, it should be an economically attractive business opportunity to recover and resell recovered Halon 1211 to the limited number of users of this material.

Rating: ***Good***

5.10 Fire Flooding Systems

5.10.1 Manufacture

Not applicable: very small losses during manufacture.

5.10.2 Servicing

An estimate of 12.3 tonnes/year is discharged due to servicing of Halon 1301 systems. This could be controlled using the Linde technology, either in a portable version used by the serviceman or as is discussed under Leaks and In-Service Emissions by a standby system installed to control emissions due to leaks or due to fires. This may be the more practical approach to control of Halon 1301, as a portable system to capture Halon 1301 during servicing may be quite cumbersome. The rating we would give to this on its own is poor to fair.

Rating: ***Poor to Fair***

5.10.3 Leaks and In-Service Emissions

Testing and training and other uncontrolled emissions of Halon 1301 were estimated by Environment Canada to be about 60 tonnes in 1987, plus emissions due to fires were estimated to be 21.7 tonnes. Banked quantities of Halon 1301 in Canada are estimated to be about 1,300 tonnes. A method we see of applying the Blue Bottle™ technology to the control of emissions from fire flooding systems is to have in place stand-by beds of adsorbent which would control discharges in the case of fires, leaks or testing of the units. Careful records of leaks, or tests, should be kept to determine whether the bed is still capable of adsorbing the Halon 1301 which would be discharged in a fire. This would be quite expensive. Installing control units for all of the banked Halons would require 13,000 tonnes of mol sieve if a 10% loading were assumed. There seems to be some movement to reserve

Halon flooding systems for only very important fire protection applications. For this more restricted use, the additional cost of the standby control systems may be quite justified.

We rate this opportunity as good. The Linde technology could work well in this application and it is an economically attractive opportunity for Linde in terms of installing systems. Linde would also have to provide a regeneration service for the loaded mol sieve and recovery of desorbed Halon 1301.

Rating: ***Good***

5.10.4 Scrap

Linde could play a role in recovering and recycling Halon 1301 being taken out of service. If we assume retiring 10% of the banked stock per year, the value of the recovered Halon 1301 at $6/lb would be about $1.7 million. The Blue Bottle™ technology would be required for in-house control of leaks from the dismantling of any Halon containing system. Much of the Halon 1301 coming out of service would be in cylinders which could readily be recycled after checking for purity. There is a minor need for the adsorption technology to control in-house emissions. Vampire units would not be appropriate for this role.

We have rated this opportunity as good, as an adjunct to other CFC/Halon related businesses for Linde.

Rating: ***Good***

5.11 Sterilant Gases

5.11.1 Manufacture

Not applicable

5.11.2 Service

Not applicable

5.11.3 Emissions in Use

Environment Canada estimates of the use of CFC 12 in sterilant gases is in the range of 550-600 tonnes per year. This is used in a mixture with ethylene oxide, Eto. 12% Eto and 88% CFC 12. It is used in health care facilities and by medical device manufacturers. The sterilization is dependent upon the Eto which, unfortunately, is toxic, mutagenic, a suspected carcinogen, flammable and explosive. It is for these reasons it is best diluted with CFC to make handling safer.

The application of the Linde technology to this area would be to capture the CFC at the discharge to the sterilizer. Because of the toxicity of Eto, the application of the technology may be after a catalytic unit designed to oxidize the Eto to carbon dioxide. The CFC 12 would be unaffected by this conversion. The Blue Bottle™ would recover the CFC 12 and the carbon dioxide would be discharged. The regeneration of the proprietary molecular sieve would probably be done by Linde at a central recovery facility because of the complications of recovering the CFC gas cryogenically (depending on the degree of dilution). For some very large volume users, it may be economical to consider on-site regeneration and recycle of CFC by blending with concentrated Eto.

The Vampire systems are not applicable to this use. The main competitive technology would be carbon adsorption. We believe that the Linde technology will result in a more complete removal of CFC from the exhaust and will be more completely regenerated with less breakdown of the recovered chemical.

The potential value of the recovered CFC is $4.8-5.3 million at $4/lb of CFC recovered.

This is seen as an excellent business opportunity for Linde as Linde markets the sterilant gas mixtures. They are already delivering these gases to the hospitals and could easily add the supply and regeneration of silicalite adsorbent to this existing business. The reclaimed CFC could be used by Linde to produce their sterilant gas product. For these reasons, this opportunity is rated as good.

Rating: ***Good***

5.11.4 Scrap

Not applicable.

5.12 Aerosols

5.12.1 Manufacture

Not applicable.

5.12.2 Service

Not applicable.

5.12.3 Leaks

Not applicable.

5.12.4 Scrap

The manufacture and sale of aerosols containing CFC is banned in Ontario as of July 1, 1990. A six month grace period is allowed to sell off any existing stock. There may be an opportunity to assist in the destruction of any residual aerosols existing January 1, 1991. Shredtech, a manufacturer of shredding equipment, has expressed an interest in providing a service to shred such containers for recovery of metal values if Linde would work with them to reclaim the CFCs. Undertaking the shredding in an enclosed area vented through a Linde canister bed would be the manner in which the technology could be applied. No estimates of the volume of CFC that might be involved is available. This is obviously not a stand-alone business opportunity, but could be an add-on to another facet of Linde's CFC recovery business, in which suitably sized adsorbent units were available and a regeneration system established. The principal CFCs used in aerosols are CFC 12 and CFC 11. Separation of these two CFCs should be relatively easy as they have such different boiling points.

We have rated this opportunity as good, mainly because the Linde technology is a most appropriate technology to solve this problem. It is not possible to quantify the amounts of CFC involved and it would probably require a strong regulatory requirement for the CFC to be recovered for this to be an economic business opportunity.

Rating: ***Good***

6. GOVERNMENT REGULATIONS

6.1 Introduction

In this Section we will discuss recommendations to government to make sure that CFC capture and recycling is undertaken for those industries who will still have to use or control CFCs or Halons for some time into the future.

Generally, CFC capture and recycling, like many other recycling initiatives, is not economically feasible based on the inherent value of the recovered material only. For solid or liquid waste recycling, these often only become feasible when the avoided cost of disposal is added to the economic benefits considered.

For some large scale prompt emission sources, such as solvent degreasing in a large electronic equipment company, capture and recycling may be economic, based on today's CFC 113 prices. For some large commercial cooling applications, the capture of the bulk of refrigerant and its re-introduction into the system after servicing may also prove economical at today's prices for CFC, or HCFC 22.

For almost all other CFC emission sources, the capture of emitted CFCs will not give sufficient return to make people want to do it from an economic benefit point of view. It is imperative, therefore, that, if government wants to ensure that emissions from these multiple small sources are captured and recycled, they enact strong specific legislation to encourage this.

Agreements, such as the Montreal Protocol and specific national governments' responses to ensure that the Protocol is followed, are fine on the manufacturing level. CFCs are produced in Canada essentially by only two companies: DuPont and Allied-Signal. Therefore, controlling production levels will be relatively easy.

Use of CFCs and Halons is extremely widespread, and, in the cases of refrigeration, air conditioning, firefighting and rigid foam, the material is banked, and will still be in use beyond the year 2000. Regulations will need to be developed to control emissions from the millions of small potential sources.

For some uses, CFC may continue into the future. Appliance manufacturers, striving to achieve energy conserving goals, have found it difficult to equal the insulating properties for rigid foam when alternative blowing agents are utilized. Thus, in this instance, one social/governmental goal may be frustrated by another social/environmental goal. With an effective capture and recycling system in place, perhaps regulations to enforce use of such a system, rather than to ban the use of CFCs, might allow both goals to be achieved.

Allowing the continued use of CFCs, however, should also require that the capture and recycling of CFCs be applied to the insulation from appliances being scrapped.

For some medical applications, such as sterilant gases, the properties of CFCs are very desirable. Again, with a good capture and recycling system in place, these materials could continue to be used in these applications.

6.2 Which Government Should Have Responsibility?

In Canada, there are three levels of government, all involved in the CFC issue. The Federal Government is obviously the level that must be involved in international agreements such as the Montreal Protocol, and in establishing national guidelines for the manufacture and use of CFCs in Canada.

Local levels of government, most notably the City of Toronto, are beginning to get involved. One area which is most appropriate for local, national and provincial governments is through their purchasing power to influence manufacturers away from the use of CFCs by demanding CFC free products. Local by-laws restricting the use of CFCs in manufacturing, the sale of CFC-containing products, or scrap goods' decommissioning are possible roles for local governments.

When it comes to regulations to ensure an effective capture and recycling approach to CFC control, the most appropriate level of government in Canada is at the provincial level. Capture of CFC is obviously an environmental emission control issue. For this, the mandate clearly rests with the provincial governments. While co-operation between the national and provincial governments through bodies such as CCEM to develop a consistent Canadian approach is very desirable, the actual responsibility for enforcement of any approach rests clearly with the Provinces.

6.3 Possible Approaches

Restating the objectives and problems: the objective is to eliminate emissions of CFC through an effective capture and recycling program. The problem is that the inherent value of the CFC that could be captured and recycled, in many instances, does not give sufficient economic incentive for it to happen.

The two broad approaches that could be considered are:

- Increase the value of the CFC to the point where it is economical to recover it through a tax on the CFC being sold.
- Enact regulations requiring that CFCs not be emitted to the atmosphere during their use in manufacture of goods, servicing and scrapping of equipment.

The United States is following this first approach with an escalating tax being applied to CFCs. Theoretically, providing the tax does not apply to recovered CFCs, this should give an incentive to recapture material. From a practical perspective, the tax would have to be quite high in order to be effective, perhaps several times the current price for CFC. The taxation approach still allows the choice of releasing the CFC rather than recapturing. The question also arises - what will the government do with the collected taxes? Would it be redistributed to encourage research into substitutes or into new recycling initiatives? Would it be used to finance recycling initiatives? Our conclusion about this approach is that, at the level that would be politically acceptable, a taxation approach might make some currently marginal recycling opportunities (e.g. large prompt emission sources) economical, but would not be effective for the myriad of small scale emissions of CFC.

The second approach, which is to enact effective regulations to encourage CFC recapture and recycling, appears to us to be the only effective way to deal with controlling CFC emissions. We believe that there should be a strong emphasis on the responsibility of the CFC "owner" in any such regulation. This would be similar to the approach of Regulation 309 to place a good deal of responsibility with a waste generator to ensure that his waste is managed properly. For a homeowner requiring servicing of a refrigerator, freezer or air conditioning system, there would be a regulatory responsibility to employ a service person who had equipment to control any emissions of CFCs for such appliances.

Also similarly to Regulation 309, there should be an obligation on the provider of services to have proper equipment to regulate the emissions of CFC during servicing of equipment and a requirement to use such equipment. Similar obligations should be placed on automobile owners and service stations that repair car air conditioning equipment.

Having recommended regulations that are similar to Regulation 309 to ensure the proper control of emissions of CFC, there is an element of Regulation 309 which may be counterproductive in promoting the capture and recycling of CFC. CFCs are currently regarded as hazardous waste, which means that every service centre that captures CFC for recycle has to register as a generator of hazardous waste, and use a licensed hazardous waste hauler to transport recaptured CFC under a manifest. Since the material is essentially the same as the refrigerant they pick up in their own vans from the wholesaler, this does not make a lot of sense from a practical point of view. Prior to getting involved in capturing emissions, service shops did not have these requirements. We have gathered from our survey that this is a very negative incentive for service people to be involved in CFC recycling.

An amendment to Regulation 309 is recommended that would relax the application of manifests and specific hauler requirements until, say, the CFC was bulked at wholesalers or, in the case of a big service operation like Sears, at a central distribution facility. The service people who handle CFCs realize that they are dealing with, in many cases, gases under pressure and that they need to handle cylinders carefully. This applies equally to new material or the captured for recycle material. Use of the Linde technology where the CFC is adsorbed on to a solid results in a low pressure recovery system which is even safer than the original CFCs from a handling point of view.

For prompt emission sources, specific emission limits similar to the proposed amended Regulation 308 would be the most appropriate method of regulation. These should be quite stringent to ensure minimum emissions for these high volume sources.

For Halons, which have such high ozone depletion potentials, controls based on controlling emissions may be more difficult to apply. The approach for regulation here may be more on restricting use and testing of fire extinguishers, particularly for portable extinguishers containing Halon 1211. For larger flooding systems, which generally use Halon 1301, a requirement could be placed on an owner of such a system to have an emission control system on standby for control during test cycles and in case of a fire. This would be quite expensive to have in place and would, therefore, encourage people to review whether they really need the Halon 1301 system. It might drastically reduce the number of Halon 1301 systems in place to only the most sensitive and valuable applications.

The final area for consideration is in the disposal of appliances, cars, materials, etc., containing CFC. This may be an area for joint action between provincial and local governments, as local governments have jurisdiction over waste disposal. A strong regulation needs to be in place prohibiting the disposal of appliances, cars, or any other material which contains CFC either directly to the landfill or to a scrap recycling operator who does not have a CFC capture and recycling system in place. As in the case of service operations, a review of requirements for handling of CFCs under Regulation 309 should be undertaken to ensure that any of these requirements are not providing a disincentive to capture and recycle CFCs.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The following are the major conclusions from the study undertaken as Phase I of the development process for the Linde CFC Capture and Recycling Technology.

1. The Blue Bottle™ can effectively capture 100% of CFC in a gas stream until it is loaded at between 3 and 15% (w/w) with the captured CFC. Lower capacities at breakthrough were observed when the adsorbent was applied to dilute streams (1,000-5,000 ppm), and higher loadings were observed when applied to concentrated streams (~ 100%). Successful tests were completed with:

   CFC 11
   CFC 12
   CFC 113
   HCFC 22
   HCFC 123
   HFC 134a

2. The loaded proprietary adsorbent can be completely regenerated by a stream of nitrogen being passed through the bed at < 500°F. No "heel" of residual CFC is left on the molecular sieve.

3. CFCs, liquid at ambient temperatures, could be readily condensed and recovered from the nitrogen stream used for regeneration. For gaseous CFCs, some redesign of our pilot scale condenser is required before reliable quantitative recovery can be demonstrated.

4. There are a number of emission sources of CFC and Halons which require control.

5. There are basically two approaches to control CFC emissions:

   - Adsorption (Linde technology, and Activated Carbon)
   - Condensation (Vampire units)

6. The Vampire units have advantages for sources, which are: undiluted 100% CFC; relatively large volume; easily accessible; and, where the condensed CFC can be returned to its original use after, say, servicing of a piece of equipment. For example:

   - Servicing of automobile air conditioners
   - Cooling equipment manufacture (where equipment has leaks in the system and needs to be emptied, fixed and refilled)
   - Servicing of commercial cooling and refrigeration systems, where those units are easily accessible.

7. Adsorption systems are the only systems that will work with streams which are less than 100% CFC. Small Blue Bottle™ canisters can be made, which are very portable, for use in difficult to access situations where relatively low volumes of CFC are involved. Some examples of applications, where the adsorption approach is advantageous, are:

   - Servicing of domestic refrigerators, freezers and air conditioner
   - Control of emissions from solvent degreasing
   - Control of emissions from flexible foam manufacture
   - Control of emissions from rigid foam manufacture
   - Control of sterilant gas emissions
   - Control of Halon emissions from flooding fire systems

- Control of residuals after vampires "empty" large commercial cooling systems and from Vampire systems themselves when changing gas streams

8. The control of CFC emissions from equipment being scrapped could be accomplished by either Vampires or adsorption systems. The choice will probably be dependent upon volume of CFC in the equipment, numbers of pieces of equipment handled, etc. To a limited extent, Vampires are already being used in this situation. Whichever technology is applied, there is a major requirement for an infrastructure to collect, purify and redistribute the recovered CFC. It cannot be returned to its original use because this equipment is now scrapped. Those companies now collecting CFC from obsolete equipment are storing the recovered chemicals, waiting for a solution.

9. A unique scrap opportunity for the adsorption approach is the recovery of CFC 11 from rigid foam insulation, both home insulation and the foam from refrigeration insulation. This would involve the recovery of both CFC and polymers or polymer chemicals.

10. There are a few potential emissions of CFC which are going to be very difficult to control for either technology. These are mainly associated with in-use leaks of equipment, e.g.:

    - Automobile air conditioning
    - Domestic cooling equipment
    - Commercial cooling equipment
    - Portable Halon 1211 fire extinguishers

    It is difficult to envision building containment systems to capture these emissions. If such systems were in place, the Blue Bottle™ technology would be the only one which could be applied.

11. There are very few control opportunities which are economically attractive at today's CFC prices and even at prices projected over the next few years as supply goes down.

12. Effective government regulation is going to be needed to require the application of control technology during equipment servicing, scrapping of CFC containing equipment, during manufacture of flexible and rigid foam and use of sterilant gases, solvents and Halon fire flooding systems.

13. In Canada, it is concluded that this could be most effectively regulated at the Provincial level.

7.2 Recommendations

It is recommended that at least two applications be selected for further testing. The two applications recommended are:

(1) Control of Sterilant Gases as an example of prompt emissions control;
(2) Capture of CFC during servicing of domestic refrigerators as an example of banked emissions control.

The work to be undertaken by Linde/ORTECH and others would be designed to:

(1) Demonstrate the efficacy of the process under field conditions;
(2) Determine the effects of impurities in the CFC streams on the initial and repeat performance of the proprietary sieve;
(3) Ensure that the recovered CFCs can be purified to meet standards for reuse;
(4) Refine the process economics;
(5) Conceptually design a commercial implementation scheme.

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APPENDIX 1 - Commercial Refrigeration & Air Conditioning

J. M. SCHNEIDER INC., 550 Kipling Avenue, Etobicoke, Ontario M8Z 5E8

Contact: Randy Smith, Maintenance Manager (416) 252-6111

Business: Produce ready to eat food products, primarily meat processing and packing facility - 25 tonnes/day of burger meats; sell to Burger King, Dairy Queen, etc.

Cooling System:

- Use ammonia, CFC (DuPont) and liquid N_2 (Linde)
- In kitchen plant, use exclusively NH_4 system (2500 T plant)

CFC Interests:

- Have CFC system that is 25 years old and which has substantial leaks
- Use CFC 12, 22, 502, for different cooling temperature ranges. Estimated 2,000 lb CFC capacity system where system leaked 2,830 lbs last year (from purchasing records)

Potential Blue Bottle™ Use Areas:

- Could be combined with leak detectors to capture in high prone leak areas
- Air exchange could be fed through mol sieve system; air has high moisture, therefore need test on mol sieve with high moisture background
- Capture in freezer room very difficult because want reduced air flow round pipes to maintain steady temperature
- Schneiders would probably be interested in recovery system when cost of CFC goes ≈ 10 times higher; at that time may also look more closely at NH_4.

Equipment Containing CFC	Type of CFC Used	Capacity of System	Quantity Lost Last Yr.	Main Leak Areas
Mobile refrigerated trucks	12			
Cold Rooms Blast Freezer (-25 to 40°F) 2 Main Long Storage Freezers (0 to -10°F) Processing (50° F and lower) Production Areas (50°F)	12 502 22 (used most)	Est. 2000 lbs designed at 500 fps	2830 lbs 12: 1300 22: 890 502: 640	150 ft tubing (old copper with high porosity) System tubing stretched to limit & sharp ends Leak areas divided 50/50 compressor/pipe area
Air Conditioning				
Old computer room (shut down) Rooftop Unit	) 3%) of) total			

Keeprite Inc., Box 460, 44 Elgin Street, Brantford, Ontario

Contact: Alan Antcliffe, General Manager of Refrigeration (519) 844-4944

Business: Manufacture unitary products, heating and air conditioning systems (units and room size), heat transfer units (heat pumps, exchangers), packaged roof top units

Range of capacity in systems - 400 lb max (evaporators and receivers). Smallest units are salad bars.

CFC Interests:

- Do not use CFC in plant any more at all
- Use only HCFC 22 for leak testing, use Van Steenburg to reclaim 22
- On newer assembly lines, use He and mass spectroscopy
- Do not charge with CFC when units finished. They are shipped out with dry air. Contractor does soap tests
- Use snap fittings on manufacture, so that only very small amount escapes
- Units last 20-25 years, depending on service (1 year parts warranty)

Concern with training of CFC handlers:

- Need certification courses rather than legislative (do not want to see ozone police)
- Want to see economic incentive to capture CFC (estimate 80% would capture if they know how and easy)
- Government should publicize more - provide videos/training
- Make sure CFC use/recovery is on curriculum of programs/apprenticeship programs
- Estimates 10-12 colleges in Canada offer courses in refrigeration repair
- HRAI programmes to become more active

Major leak areas:

- Greatest leaks occur in field welded connections
- Do not supply valves (would wait until it was legislated so everybody is doing it - otherwise economic disadvantage)
- Estimated that 80% are good welders
- Suggest the more valves, the greater potential for leaks to occur
- Have vibration isolation and pump down receivers in units.

Hussman Store Equipment Ltd., 58 Frank Street, Box 558, Brantford, Ontario N3T 5R2

Contact: Mr. Norm Panabaker, V.P. Engineering (519) 844-8661

Business: Manufacture self contained refrigerators, i.e. modular, Foodstore displays, reach in store refrigerators

Size of charges: 1000 to 1400 lbs in supermarket (large ones 2-3 x this size). 800 lbs per smaller units

Over 500 employees manufacture 100-200 cases/week

CFC Interests:

Testing

- Use HCFC 22 (4-5% with dry air/nitrogen) in testing
- Only have 2 small product lines left that use R12
- Self contained systems - meat cases
  Deli cases
  Dairy cases in convenience stores

Installation

- Has own service technician to start up
- Sell to big chains who buy direct, i.e. Loblaws/Co-ops/A & P
- Smaller dairies - these are distributed through contractors
  1 year warranties

Service area

- With own warranty program they replace CFC discharged due to warranty item failures - estimate 2000 lbs of CFC = 1 year
- Could see use of "Blue Bottle™" to recover small quantities, i.e. purge lines (standard length 48-60" - 3/16" ID, where, on high side of system hose is cool enough to have liquified CFCs
- No idea of what % of CFC lost through leaks in service
- Could braze all connections to reduce leakage, but this would mean longer time in servicing by servicemen
- Estimated costs of CFCs for servicemen:
  (115/22) 502 ~ $8/kg
  R12 $6/kg
- Recognize that better reclamation systems are needed for rooftop unit servicing, i.e. carry unit to top; need power at the top; used in all types of weather

Foam Blowing of Insulation

- Use of CFC 11 (96%) and CFC 12 (4%) in foaming
- Do not know how much they purchase
- Use MeCl to clean guns that blow foam
- Have ventilation system that draws from the floor
- Use MDI in foam mixture that could foul the CFC gases reclamation process

Carrier Canada Limited, (including ACR, AIRCO, dsf, Werners), Meadowvale Atrium, 1900 Minnesota Court, Suite 200, Mississauga, Ontario L5N 5R5

Contacts:	Nicholas Falaleeff, National Manager, Safety & Industrial Hygiene Al Gillies, Director of Business Development, CBS and Controls J. Duncan Cochrane, Technical Services Support Manager (416) 826-9508
Business:	The world's largest manufacturer of heating and cooling systems (especially centrifugal chillers) equipment Subsidiary of UTC (United Technologies Corporation) which provides a broad range of high technology products and support services to aerospace, building systems and automotive industries Have own distribution centres where their contractors and others come for equipment and gases Have over 17,000 employees; 60-80 Branches across Canada Are presently rewriting job descriptions to include environmental concerns

CFC Interests:

- Investing over $70 million over next 5 years to help phase out CFC in air conditioners and to develop equipment to recover and recycle existing refrigerants
- Announcement includes:
  (1) Refrigerant Management Systems (RMS) which recover and recycle CFC 11 in quantities up to 3,300 lbs as found in commercial chillers
  (2) ST 100 recovery system which recycles CFC used in truck/trailer refrigeration systems
  (3) Introduction of additional commercial chillers that use CFC 22 and offer chillers that can operate on HCFC 123
  (4) PRE-VAC (TM) system for centrifugal chillers that reduces refrigerant purge requirements. It works by preventing air infiltration when chiller is idle which eliminates the need to purge this air along with some CFC, thereby reducing purged CFC
  (5) Will introduce a new high efficiency purge unit to reduce CFC emissions by 10 x during chiller purging

(6) Introduction of advanced leak detection equipment is under development to allow immediate identification of CFC emissions

(7) Conducting research to develop air conditioning and refrigeration equipment that is compatible with HCFC 134a

(8) Writing a new Code of Practice for installing and servicing its equipment that incorporates and requires the proper procedures for recovery and recycling of CFC

Copeland Refrigeration of Canada Ltd., Box 1060, Brantford, Ontario N3T 5S7

Contacts: Cory Stroud, President; Bill Mead. (519) 756-6157

Business: Manufacture compressors for the Refrigeration and Air Conditioning industry; presently employ ~ 60 people at Brantford facility

Remanufacture old compressors on site (50% of business)

CFC Interests:

- Use CFC in leak testing (25% R12 with N_2) to detect 1 oz/10 years leak sensitivity
- Purchase 4000 kg/year of R12 mix
- Presently purge to atmosphere

Testing procedure:

- Heat unit to drive out moisture
- Pressure test/water leak test (10-20 mins)
- Pressure test - full charge with R12 - electronic leak test (1/2 hr)
- When units pass test, will recharge with 15 lb dry N_2 and ship to equipment manufacturers (i.e. Hussman, Keeprite)
- Average # of units/day - 60-80 (1/4-3/4 HP)

Compressor failures:

- 90% are system failures or poor servicing
- 10% oil runs out/overheated
- Average life span is 9 years

- Concerns with recycled CFCs are that they are guaranteed to spec
- Would like regulations to guarantee purity

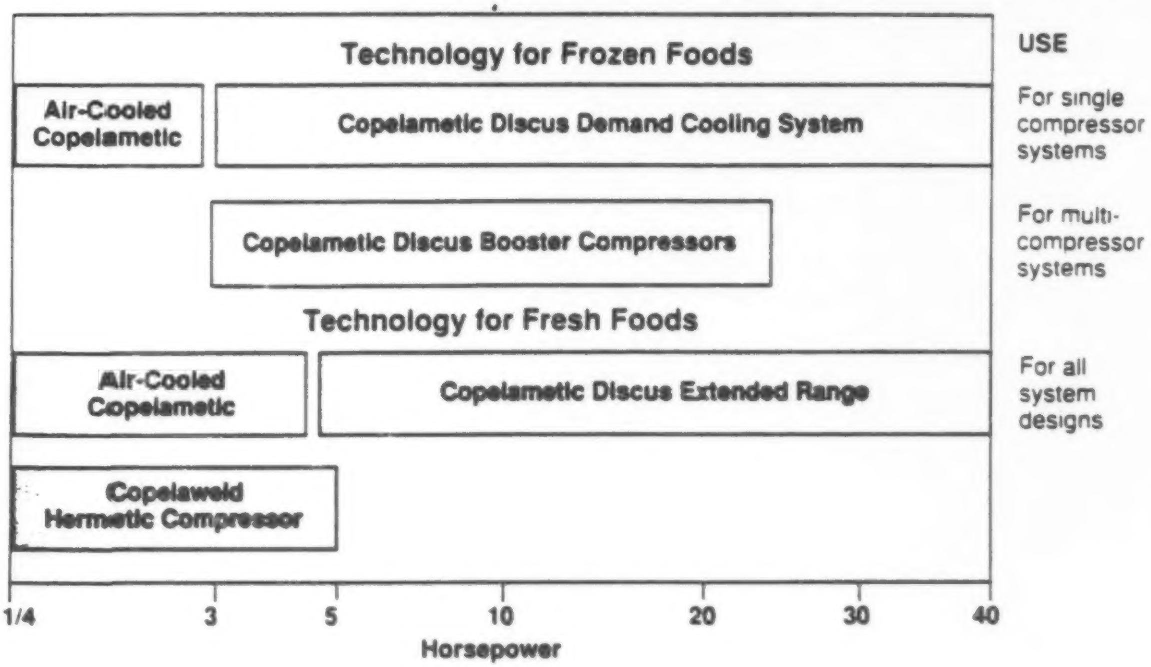
Reclamation systems:

- Are investigating potential use of other materials(i.e. 22) for leak testing
- Need systems that evacuate 1 ft^3 in less than 1 min; have reviewed Van Steinburg - think that it can do it; Robinair - think that it cannot
- Interested in "Blue Bottle™" but want to see how it works under a vacuum
- Perhaps one use of Blue Bottle™ would be to remove CFC immediately from testing area to ensure uncontaminated testing area

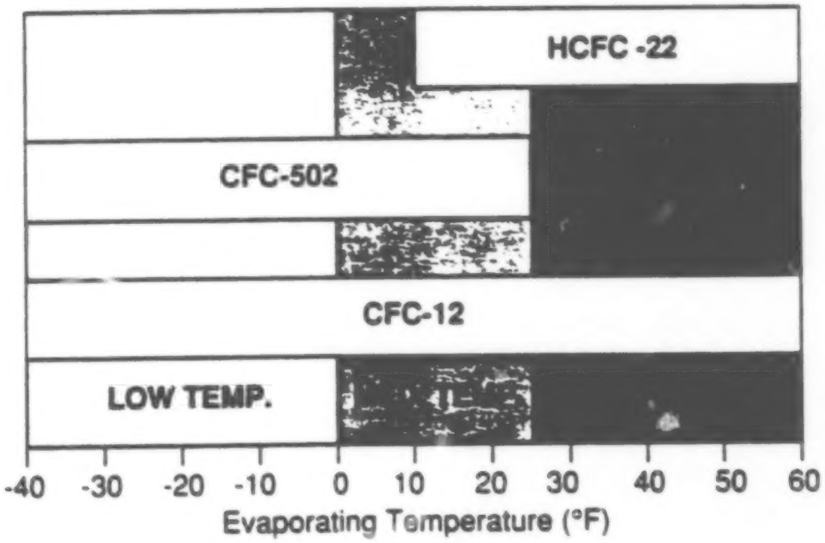
Copelands:

- 5 point action plan related to CFC reduction
  1. Waiting for new refrigerants not in best interest
  2. Move away from CFC 12 applications quickly
  3. Avoid field retrofitting CFC 12 systems with alternate refrigerants
  4. Practice greater conservation
  5. Continue to use CFC 502 for low temperature applications until alternate one is fully understood. Copeland is developing compressor technologies for HCFC 22 applications. (See following diagrams from Copelands reports)

Compressor Technologies for HCFC-22 Application



Typical Refrigerant Application Ranges



Accutherm Refrigeration Ltd., 100 Turbine Drive, Toronto, Ontario M9L 2S2

Contact:: Bert Rittberger, owner (416) 746-1148

Business: Service and installation of commercial and institutional large scale refrigeration systems (50% service, 50% installation)

Shop is primarily storage area for materials such as parts, CFC, recycling system that needs to be used on job site

Do approximately 4 calls/day

CFC Interests:

- Use CFC 12 (Allied Signal), 502, 22, some still sold in non-refillable containers

Recycling system: have devised own recovery unit as follows:

Connector hose - filter system for oil trap - 1 HP compressor with 110 v service - coded container to recover CFC

- System approximately 3 ft x 7 ft long
- Has capacity to recover 60 lbs CFC liquified/hr
- Often returns CFC back to system after maintenance
- Reintroduction of CFC to a system under vacuum takes 10 mins for 60 lbs

Contaminant check on CFC before reintroduction:

- If system has motor burnout, then need to check for breakdown products in CFC
- 10 min reaction test that actually tests for moisture as indicator in CFC
- CFC can be passed through filter system again and reintroduced, if found to be contaminated from first test

Leak testing in service:

- Presently use 5% CFC mixture (with N_2) for leak tests
- Use TIF automatic halogen detectors (Miami, Florida) which can detect 1/2 oz per year leak rates
- Cost ~ $400 9 years ago (very good detector)
- Leak alert indicated by frequency tone change
- Problem in windy areas; also measures CFC in background
- Other detectors, i.e. Robinair, $268

Potential for Blue Bottle™ use:

- Capture of residual CFC when recovery system emptied (vacuuming or blown) to change gases; all residual gas must be removed to prohibit mixing of gases; this could be in home made units or in commercial units
- Capture dilute stream from leak detection

Other suggestions:

- Need to ensure (regulatory help needed) that systems are equipped with double valve systems for good bleeding when required
- Need reusable/deposit system CFC containers

Power Watch Industries, 109 McMaster Road, Ajax, Ontario L1S 2E6

Contact: Ed Barlow, Greg Evans (416) 683-6847

Business: Heating, ventilation and air conditioning service industry in business for last 15 years. Not members of any associations. New interest is CFC recovery of scrap and demolition goods

CFC Interests:

- Reclaims CFC from scrap goods now with own unit (RMS 2000 from ENSPECO $3,000), a unit which he prefers to others he has tested (i.e. moisture analysis from RMS 2000 ~ 249 ppm [has sporolin driers]. From Robinar ~ 500 ppm)
- Has reclaimed HCFC 22 from commercially scrapped room air conditioners from major hotel chains in Toronto who specifically request this in their tenders (i.e. Manulife Centre)
- Has collected and recovered HCFC 22 and donated some to ORTECH for analysis
- Would like to become a depot for spent CFC collected from other servicemen and transfer to Linde for cleanup/or Linde could supply Linde adsorption bed technology licence for own purification system
- Has talked with Lasco and Durham Region about recovery from scrapped cars and white goods and is also demanufacturing and recycling components of scrapped air conditioning parts, i.e. copper tubing, plastic parts, wires, scrap metal
- Has proposed to MOE to set up CFC recovery from scrapped goods and has applied for waste receiver site
- Also working with Chromolux industries who want to be the first manufacturers utilizing recovered CFC in air conditioning units (in for CSA approval) and is very interested in retrofit market
- Has also talked to Environment Canada about Code of Practice for scrap demolition CFC recovery - they are interested but cannot give him seal of approval for process but may give letter of intent to say PWI will be operating as a potentially certifiable facility

Concerns:

- Need to have recovered CFC that meets specs so that it can be used safely in new air conditioning units
- Wants to see CFC put into new units and that data are kept on what equipment contains CFC and where it goes. He suggests we do not know enough about it to let it be used now without tracking
- Servicemen need a very easy system to recover from units

U.S. Navy, Department of Navy, NAVSEA, Washington, D.C., U.S.A. 20362

Contact: Jim Decorzro (703) 602-5307

Business: Responsible for CFC use in submarines

CFC Interest:

- Interested in use of Blue Bottle™ to capture CFC on board. Will review information with colleagues

Heating, Refrigeration and Air Conditioning Institute of Canada (HRAI)

5468 Dundas Street West, Suite 308, Islington, Ontario M9B 6E3

Contact: Warren Heeley, President (416) 239-8191

HRAI: Has over 1000 members across Canada from the manufacturers, wholesalers, suppliers or contractors of equipment, parts, accessories and service for the HVACR industry. Other members include associates from the educational, government and consultant fields. Many of its members appear to be more related to the heating and ventilation area rather than air conditioning and refrigeration.

The association members are those in the area of commercial/industrial/institutional refrigeration

- They presently have a CFC user group
- Estimate over 10,000,000 existing commercial units at present here in Canada
- 80-90% of market for CFC within industry is in the after market or service sector
- Manufactured systems consist of 2 primary kinds:
  - (1) Engineered Systems - Hussman
    - General Refrigeration
  - (2) Unitary Systems - Keeprite (unitary products)
    - Copeland (compressor mfgr)
    - Hussman (to supermarkets)
- Dun & Bradstreet estimate of over 6000 industries related to this area in 1985
- Opportunity to collect CFC from servicing commercial equipment with motor or compressor burnout; less of an opportunity exists for leak areas
- Indicated Yorx has a chiller in Ottawa operating on HCFC 123a as a substitute for 11
- Presently no drop in substitutes in commercial refrigeration and air conditioning, but certain systems can be modified to accept alternate CFC mixtures such as CFC 500 and CFC 502; limited opportunities for conversion and retrofit in field due to existing stock unit estimates
- Low pressure chillers and low temperature refrigeration units do not have alternate design options at this time
- Can be some design modification for use of lower ODP refrigerants but this equipment needs lead time and consumer demand

Regulatory Recommendations:

- Have responded to Environment Canada draft plan for reduction of CFCs by encouraging the implementation of a conversion strategy (i.e. using HCFC 22 and R502 where eligible
- Also want residential air conditioning systems to be removed from the plan since they operate on HCFC 22
- Are stressing the importance of Environment Canada and MOE designate CFCs as a recyclable material rather than a hazardous waste to ease the restriction and encourage collection and recycling
- Also want Ontario MOE to consider spent refrigerant oil containing CFCs as recyclable material, not hazardous waste

HRAI has developed a set of action guidelines for reduction of controlled CFCs as included.

Training Program:

- HRAI and federal government developing an education program to train service technicians in the refrigeration and air conditioning industry in the safe handling of CFC which is to be completed by the end of August
- Project includes development of complete training program and production of user-oriented video (English and French) and establishment of a certification program

HRAI ACTION GUIDELINE FOR REDUCTION OF USE OF CONTROLLED CFC's/

The Canadian refrigeration and air conditioning industry, with the support of HRAI, will take the following steps to reduce the use of controlled CFC's 11, 12, 113, 114 and 115:

1. DESIGN NEW SYSTEMS FOR CFC-22 OR OTHER LOWER OR NON-OZONE DEPLETING REFRIGERANTS

Recognizing that there are certain uses where alternatives are not presently available, such as centrifugal chillers, all new industrial and commercial refrigeration and air conditioning systems should be designed to operate on CFC-22 or an alternate refrigerant with lower or no ozone depleting potential.

2. INCORPORATE RECEIVERS AND ISOLATING VALVES IN NEW SYSTEMS

The design of new installations should incorporate means such as receivers sized to contain the full charge of the system and adequate isolating valves to minimize blow-off and refrigerant loss during service.

3. DO NOT USE CFC 11 OR 113 FOR FLUSHING

The use of CFC-11 and 113 in the flushing of refrigeration and air conditioning systems should be replaced by alternate cleaning methods such as the filter-drier or other available methods.

4. USE RECEIVERS DURING SERVICING OF SYSTEMS

All refrigeration and air conditioning systems should be pumped-down and contained in a receiving vessel (whether part of the system or separate) so that no refrigerant is vented to the atmosphere.

5. REUSE, RECOVER AND RECYCLE REFRIGERANTS, WHERE POSSIBLE

Where of acceptable quality, refrigerant should be reused in every case. Where refrigerant is not of an acceptable quality for immediate reuse, then recovery and recycle methods should be carried out, where possible.

6. REPLACE CFC-12 WITH ENVIRONMENTALLY SAFER REFRIGERANTS WHERE FEASIBLE

When servicing CFC-12 refrigeration and air conditioning systems, replacement of CFC-12 with environmentally safer refrigerants should be considered where it is practical and recommended by the equipment manufacturer.

7. PRESSURE TEST WITH INERT GASES AND ENSURE ALL SYSTEM PIPING IS TIGHT

Pressure testing of refrigeration and air conditioning systems should not be done with CFC-12; instead, other available environmentally safe alternates must be used.

8. DO NOT USE 1 POUND CANS OF REFRIGERANT

The use of 1 pound refrigerant containers shall be eliminated because of the high percentage of refrigerant loss from the container.

Air Conditioning & Refrigeration Institute (ARI)
1501 Wilson Boulevard, Arlington, Virginia, U.S.A. 22209

Contact: Arnold Bruswell, President

CFC Interest:

- Have developed CFC Standards for use in refrigerants (see attached)

1988
STANDARD for

SPECIFICATIONS FOR FLUOROCARBON REFRIGERANTS

Standard 700

IMPORTANT

Safety Recommendations

Procedures in this standard may involve hazardous materials, operations and equipment. This standard does not purport to address all the safety problems that might be associated with its use. It is the responsibility of whomever uses this standard to identify and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Information may be obtained from ANSI/ASHRAE Standard 15, "Safety Code for Mechanical Refrigeration," the refrigerant manufacturers and other sources.

FOREWORD

The intent of this standard is to define a level of quality for new, reclaimed and/or repackaged refrigerants for use in new and existing refrigeration and air-conditioning products within the scope of ARI.

Contaminant limits were chosen to be within the sensitivity of recommended test methods, to be economically achievable by current processes and to provide satisfactory performance of these products.

This standard does not apply where refrigerant captured from a particular system is returned on site to the same system.

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SPECIFICATION FOR FLUOROCARBON REFRIGERANTS

Section 1. Purpose

1.1 *Purpose.* The purpose of this standard is to enable users to evaluate and accept/reject refrigerants regardless of source (new, reclaimed and/or repackaged) for use in new and existing refrigerating and air conditioning products within the scope of ARI.

1.1.1 This standard is intended for the guidance of the industry, including manufacturers, refrigerant reclaimers, repackagers, distributors, installers, servicemen, contractors and for consumers.

1.2 *Review and Amendment.* This standard is subject to review and amendment as the technology advances.

Section 2. Scope

2.1 *Scope.* This standard defines and classifies refrigerant contaminants primarily based on standard and generally available test methods and specifies acceptable levels of contaminants (purity requirements) for various fluorocarbon refrigerants regardless of source. These refrigerants are: R11; R12; R13; R22; R113; R114; R500; R502 and R503 as referenced in the ANSI/ASHRAE Standard "Number Designation of Refrigerants" (American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., Standard 34-78).

Section 3. Definitions

3.1 *"Shall", "Should", "Recommended",* or *"It Is Recommended".* "Shall", "should", "recommended", or "it is recommended" shall be interpreted as follows:

3.1.1 *Shall.* Where "shall" or "shall not" is used for a provision specified, that provision is mandatory if compliance with the standard is claimed.

3.1.2 *Should, Recommended,* or *It is Recommended.* "Should", "recommended", or "it is recommended" is used to indicate provisions which are not mandatory but which are desirable as good practice.

Section 4. Characterization of Refrigerants and Contaminants

4.1 Characterization of refrigerants and contaminants addressed are listed in the following general classifications:

4.1.1 *Characterization*
   a. Boiling point
   b. Boiling point range

4.1.2 *Contaminants*
   a. Water
   b. Chloride ion
   c. Acidity
   d. High boiling residue
   e. Particulates/solids
   f. Non-condensables
   g. Other refrigerants

Section 5. Sampling, Test Methods and Maximum Permissible Contaminant Levels

5.1 The recommended referee test methods for the various contaminants are given in the following paragraphs. If alternate test methods are employed, the user must be able to demonstrate that they produce results equivalent to the specified referee method.

5.2 *Refrigerant Sampling.*

5.2.1 Special precautions should be taken to assure that representative samples are obtained for analysis. Sampling shall be done by trained laboratory personnel following accepted sampling and safety procedures.

5.2.2 *Gas Phase Sample.* A gas phase sample shall be obtained for determining the non-condensables by connecting the sample cylinder to an evacuated gas sampling bulb by means of a manifold. The manifold should have a valve arrangement that facilitates evacuation of all connecting tubing leading to the sampling bulb. Since non-condensable gases, if present, will concentrate in the vapor phase of the refrigerant, care must be exercised to eliminate introduction of air during the sample transfer. Purging is not an acceptable procedure for a gas phase sample since it may introduce a foreign product. Since R11 and R113 have normal boiling points at or above room temperature, non-condensable determination is not required for these refrigerants.

5.2.3 *Liquid Phase Sample.* A liquid phase sample, which may be obtained as follows, is required for all tests listed in this standard, except the test for non-condensables. Place an empty sample cylinder with the valve opened in an oven at 230°F [110°C] for one hour. Remove it from the oven while hot, immediately connect to an evacuation system and evacuate to less than 1 mm. mercury (1000 microns). Close the valve and allow it to cool.

5.2.3.1 The valve and lines from the unit to be sampled shall be clean and dry. Connect the line to the sample cylinder loosely. Purge through the loose connection. Make the connection tight at the end of the purge period. Take the sample as a liquid by chilling the sample cylinder slightly. Do not load the cylinder over 80 percent full at room temperature. This can be accomplished by weighing the empty cylinder and then the cylinder with refrigerant. The cylinder must not become completely full of liquid below 130°F [54.4°C]. When the desired amount of refrigerant has been collected, close the valve(s) and disconnect the sample cylinder immediately.

5.2.3.2 Check the sample cylinder for leaks and record the gross weight.

5.3 *Refrigerant Boiling Point and Boiling Range*

5.3.1 The test method shall be that described in the Federal Specification for "Fluorocarbon Refrigerants" BB-F-1421 B dated March 5, 1982, section 4.4.3.

5.3.2 The required values for boiling point and boiling point range are given in Table 1, "Physical Properties of Fluorocarbon Refrigerants and Maximum Contaminant Levels."

5.3.3 Gas chromatography (GC) is an acceptable alternate test method which can be used to characterize refrigerants. This is done by comparison to be known standards. Listed below are some readily available GC methods.

Alternate Gas Chromatography Test Methods

(See Appendix A for titles and sources)

Refrigerant	ICI	Dupont	Allied
R11	RSV/ALAB/CM3 and RSV/ALAB/CM4	F3205.165.01CW	G-11-7A
R12	RSV/ALAB/CM5	F3227.165.01CW(P)	G-12-7A
R13	RSV/ALAB/CM20	F3275.165.01CC(P)	—
R22	RSV/ALAB/CM8	F3290.165.01LV(P)	G-22-7A
R113	RSV/ALAB/CM6	F3297.165.01CC	GSVD-1A
R114	RSV/ALAB/CM21	F3305.165.01CC(P)	G-114-7A
R500	RSV/ALAB/CM5	F3327.165.01CW(P)	G-500-7A
R502	RSV/ALAB/CM8	F3333.165.01CC	G-502-7A
R503	RSV/ALAB/CM20	F3337.165.01CW(P)	G-503-7A

Note: Equivalent laboratory test methods may be available from other producers of these refrigerants

5.4 *Water Content*

5.4.1 The Karl Fischer Test Method shall be used for determining the water content of refrigerant. This method is described in ASTM Standard for "Water In Gases Using Karl Fisher Reagent" E700-79, reapproved 1984 (American Society for Testing Materials, Philadelphia, PA). This method can be used for refrigerants that are either a liquid or a gas at room temperature, including Refrigerants 11 and 113. For all refrigerants, the sample for water analysis shall be taken from the liquid phase of the container to be tested. Proper operation of the analytical method requires special equipment and an experienced operator. The precision of the results is excellent if proper sampling and handling procedures are followed. Refrigerants containing a colored dye can be successfully analyzed for water using this method.

5.4.2 Water is a harmful contaminant in refrigerants because it causes freeze up, corrosion and promotes unfavorable chemical breakdown. The refrigerants covered in this standard shall have a maximum water content of 10 parts per million (ppm) by weight.

5.5 *Chloride Ions.* The refrigerant shall be tested for chlorides as an indication of the presence of hydrochloric or similar acids.

5.5.1 The test method shall be that described in the Federal Specification for "Fluorocarbon Refrigerants," BB-F-1421B, dated March 5, 1982, (U.S. General Services Administration) section 4.4.4 (silver nitrate reagent). This simple test will detect HC1 and other halogens and requires only a 5 ml; sample. The test will show noticeable turbidity at equivalent HC1 levels of about 25 ppm by weight or higher.

5.5.2 The results of the test shall not exhibit any sign of turbidity. Report the results as "pass" or "fail."

5.6 *Acidity*

5.6.1 The acidity test uses the titration principle to detect any compound that ionizes as an acid. The test requires about a 100 to 120 gram sample and has a lower detection limit of 0.1 ppm by weight.

5.6.2 The test method shall be per Allied approved analytical procedure "Determination of Acidity in Genetron® and Genesolv® Fluorocarbons," GP-GEN-2A (used by permission of Allied-Signal, Inc., Columbia Road and Park Avenue, P.O. Box 1139R, Morristown, New Jersey 07960), or DuPont procedure, "The Determination of Acid Number—Visual Titrimetric Procedure," FPL-3-1974 (used by permission of Freon Products Division E.I. duPont de Nemours and Co., Inc., Brandywine Building 13237, Wilmington, Delaware 19898).

5.6.3 The maximum permissible acidity is 1 ppm by weight.

5.7 *High Boiling Residue*

5.7.1 High boiling residue will be determined by measuring the residue after evaporation of a standard volume of refrigerant at a temperature 50°F [10.0°C], above the boiling point of the sample using a Goetz tube as specified in the Federal Specification for "Fluorocarbon Refrigerants," BB-F-1421B, dated March 5, 1982. Oils and organic acids will be captured by this method.

5.7.2 The value for high boiling residue shall be expressed as a percentage by volume and shall not exceed the maximum percent specified in Table 1.

5.8 *Particulates/Solids*

5.8.1 During the Boiling Range test, a measured amount of sample is evaporated from a Goetz bulb under controlled temperature conditions. The particulates/solids shall be determined by visual examination of the empty Goetz bulb after the sample has evaporated completely. Presence of dirt, rust or other particulate contamination is reported as "fail."

5.8.2 For details of the above test method, refer to the DuPont method for "Determination of Boiling Range, Residue, Particulates" F3200.037.01CW(P) (used by permission of Freon Products Division, E.I. duPoint de Nemours and Co., Inc.).

5.9 *Non-Condensables*

5.9.1 Non-condensable gases consist primarily of air accumulated in the vapor phase of refrigerant-containing tanks. The solubility of air in the refrigerants liquid phase is extremely low and air is not significant as a liquid phase contaminant. The presence of non-condensable gases may reflect poor quality control in transferring refrigerants to storage tanks and cylinders.

5.9.2 The test method shall be that described in the Federal Specification for "Fluorocarbon Refrigerants," BB-F-1421B, dated March 5, 1982, section 4.4.2 (perchloroethylene method). Gas Chromatography, as described in 5.3.3 is an acceptable alternate test method.

5.9.3 The maximum level of non-condensables in the vapor phase of a refrigerant in a container shall not exceed 1.5 percent by volume.

5.10 *Other Refrigerants*

5.10.1 The amount of other refrigerants in the subject refrigerant shall be determined by one of the gas chromatographic methods described in 5.3.3 for the appropriate refrigerant.

5.10.2 The subject refrigerant shall not contain more than 0.5 percent by weight of other refrigerants (see Table 1).

Section 6. Reporting Procedure

6.1 The source (manufacturer, reclaimer or repackager) of the packaged refrigerant should be identified. The fluorocarbon refrigerant shall be identified by its accepted refrigerant number and/or its chemical name. Maximum permissible levels of contaminants are shown in Table 1. Test results shall be tabulated in a like manner.

Section 7. Voluntary Conformance

7.1 *Voluntary Conformance.* Conformance to this standard is voluntary. However, any refrigerant specified as meeting these requirements shall meet all of the requirements given in this standard.

Table 1. Physical Properties of Fluorocarbon Refrigerants and Maximum Contaminant Levels

	REFRIGERANTS								
	R11	R12	R13	R22	R113	R114	R500	R502	R503
PHYSICAL PROPERTIES Boiling point F @ 29.92 in. Hg	74.9 [23.8]	−21.6 [−29.8]	−114.6 [−81.4]	−41.4 [−40.8]	117.6 [47.6]	38.8 [3.8]	−28.3 [−33.5]	−49.8 [−45.4]	−127.6 [−88.7]
Boiling range °F for 5% to 85% by volume distilled	0.5	0.5	0.9	0.5	0.5	0.5	0.9	0.9	0.9
VAPOR PHASE CONTAMINANTS Air and other non-condensables (in filled container) Max. % by volume	—	1.5	1.5	1.5	—	1.5	1.5	1.5	1.5
LIQUID PHASE CONTAMINANTS Water— ppm by weight	10	10	10	10	10	10	10	10	10
Chloride ion—no turbidity to pass by test	pass	pass	pass	pass	pass	pass	pass	pass	pass
Acidity— Max. ppm by weight	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
High boiling residues—Max. % by volume	0.01	0.01	0.05	0.01	0.03	0.01	0.05	0.01	0.01
Particulates/Solids—visually clean to pass	pass	pass	pass	pass	pass	pass	pass	pass	pass
Other refrigerants—Max. % by weight	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Appendix A
Titles and Sources of Alternate Gas Chromatography Test Methods

ICI

General Chemical Business
ICI Chemicals and Polymer Ltd.
P.O. Box 13
The Heath
Runcorn Cheshire, England WA74QF

Methods for the Analysis of "Arctons," MD1400/32 "Organic Impurities by Gas Chromatography"

Refrigerant	Method Number	Title
R11	RSV/ALAB/CM3 and RSV/ALAB/CM4	Arcton 11
R12	RSV/ALAB/CM5	Arcton 12
R13	RSV/ALAB/CM20	—
R22	RSV/ALAB/CM8	Arcton 22
R113	RSV/ALAB/CM6	Arcton 113
R114	RSV/ALAB/CM21	Arcton 114
R500	RSV/ALAB/CM5	—
R502	RSV/ALAB/CM8	—
R503	RSV/ALAB/CM20	—

(Note: Used with permission of the source.)

DuPont

Freon Products Division
E.I. duPont de Nemours and Co., Inc.
1007 Market Street
Wilmington, Delaware 19898

Refrigerant	Method Number	Title
R11	F3205.165.01CW	Determination of Purity by Gas Chromatography "Freon" 11 Fluorocarbon
R12	F3227.165.01CW(P)	"Freon" 12 Determination of Purity
R13	F3275.165.01CC(P)	Determination of Composition "Freon" 13 Fluorocarbon
R22	F3290.165.01LV(P)	"Freon" 22 Determination of Purity by Gas Chromatography
R113	F3297.165.01CC	"Freon" 113 Determination of Purity by Gas Chromatography
R114	F3305.165.01CC(P)	"Freon" 114 Fluorocarbon—Determination of Composition
R500	F3327.165.01CW(P)	"Freon" 500 Determination of Composition by Gas Chromatography
R502	F3333.165.01CC	"Freon" 502 Determination of Composition by Gas Chromatography
R503	F3337.165.01CW(P)	"Freon" 503 Determination of Composition

(Note: Used with permission of the source.)

Allied

Allied-Signal, Inc.
Engineered Material Sector
P.O. Box 1139R
Morristown, New Jersey 07960

Refrigerant	Method Number	Title
R11	G-11-7A	Determination of Genetron® 11 Fluorocarbon (Assay) Fluorocarbon 12, Carbon Tetrachloride, and Non-Specified Fluorocarbons in Genetron® 11 Fluorcarbon.
R12	G-12-7A	Determination of Genetron® 12 Fluorocarbon (Assay), Fluorocarbons 11, 13, 22 and Non-Specified Fluorocarbons in Genetron® 12 Fluorocarbons.
R13	—	—
R22	G-22-7A	Determination of Genetron® 22 Fluorocarbons (Assay), Fluorocarbons 12, 21, 23 and Non-Specified Fluorcarbons in Genetron® 22 Fluorocarbons.
R113	GSVD-1A	Determination of Genesolv® D (Assay), Fluorocarbons 112, 114, 122, 123 and 1112a In Genesolv® D.
R114	G-114-7A	Determination of Genetron® 114 Fluorocarbon (Assay), Fluorocarbons 113, 115, 123, and Non-Specified Fluorocarbons in Genetron® 114 Fluorocarbon.
R500	G-500-7A	Determination of Fluorocarbon 12, Fluorocarbon 152a and Non-Specified Fluorocarbons in Genetron® 500 Fluorocarbon.
R502	G-502-7A	Determination of Fluorocarbon 22 and Fluorocarbon 115, and Non-Specified Fluorocarbons in Genetron® 502 Fluorocarbon.
R503	G-503-7A	Determination of Fluorocarbon 13, 23, [illegible] 22 and Non-Specified Fluorocarbons in Genetron® 503 Fluorocarbon.

(Note: Used with permission of the source.)

Bibliography

For additional information on subjects or tests described in this Standard see:

1. ASHRAE Handbook *Refrigeration 1986*. Chapter 7. "Moisture and Other Contaminant Control in Refrigerant Systems." American Society for Heating, Refrigeration and Air Conditioning Engineers, Inc., Atlanta, GA 30329
2. ASTM Standard Designation D3401-78. Standard Test Method for "Water in Halogenated Organic Solvents and Their Admixtures" American Society for Testing Materials, 1916 Race Street, Philadelphia, PA 19103.
3. ASTM Standard D1533-83, "Water in Insulating Liquid (Karl Fischer Reaction Method)." American Society for Testing Materials, 1916 Race Street, Philadelphia, PA 19103.
4. ASTM Standard 2989-74 (reapproved 1981), Standard Test Method for "Acidity—Alkalinity of Halogenated Organic Solvents and Their Admixtures." American Society for Testing Materials, 1916 Race Street, Philadelphia, PA 19103.
5. DuPont Technical Bulletin B-8, "Quality Specifications and Methods of Analysis for the 'Freon' Fluorocarbon Refrigerants." Freon Products Division, E.I. duPont de Nemours and Co., Inc.
6. Parmelee, H. M. "Solubility of Air in Freon-12 and Freon-22" Refrigerating Engineering, June 1951 page 573.
7. Wojtkowski, E. F. "System Contamination and Cleanups," ASHRAE Journal, June, 1964 page 49.

American Society of Heating, Refrigeration and Air Conditioning Engineers Inc.(ASHRAE)
1891 Tuille Circle, NE, Atlanta, Georgia, U.S.A. 30329

Contact:	(404) 636-8400
ASHRAE:	Industrial trade association which has the following interests in serving its membership: consulting, merchandising and sales, contracting and service, utilities, manufacturing and teaching and research.

List of CFC Wholesalers and Distributors in Canada

Monclair-Prokontrol Inc.
P.O. Box 10
St-Joseph de Beauce, Que.
G0S 2V0

Attn: Mme Georgette Verebely
Service a la clientele

Trane Canada Inc.
401 Horner Avenue
Toronto, Ontario
M8W 2A5

Attn: Mr. Richard Yu
Manager, Refg. Sales Dept.

United Refrigeration & Heating
Div. of Westburne Inc.
1365 Erin Street, P.O. Box 519
Winnipeg, Man
R3C 2J8

Attn: Mr. Blair Hill
Purchasing Manager

Refrigerative Supply
132 West 2nd Avenue
Vancouver, B.C.
V5Y 1C2

Attn: Mr. Peter Gibbs
General Manager

Southern Supplies Ltd.
323 Bloor St. West
Oshawa, Ontario
L1J 6X4

Attn: Mr. Walter E. Libby
Assistant Controller

York Air Conditioning Ltd.
375 Matheson Blvd. E
Mississauga, Ontario
L4Z 1X8

Attn: Mr. T. W. Frith
National Sales Manager

St. Lawrence Chemicals Inc.
19201 avenue Clark Graham
Baie d'Urfe, Quebec
H9X 3P5

Attn: M. Russ Cully
Product Manager

Que-Mar Refrigeration Inc.
405 Boul. Montpellier
St-Laurent, Que
H4N 2G6

Attn: M. Albert Couture
President

R. L. Fulton Equipment Ltd.
5654 Russel St., P.O. Box 1402N
Halifax, N.S.
B3K 5H7

Attn: Mr. J. Thomas
General Manager

Marshall Refrig. Co. Ltd.
130 Riviera Drive
Markham, Ontario
L3R 5M1

Attn: Mr. W. F. Marshall
President

Temtro Refrigeration Distr. Ltd.
907-34 Avenue S.E.
Calgary, Alberta
T2G 5H6

Attn: Mr. H. Paulley
General Manager

Refac Division Westburne
6655 Bombardier
St-Leonard, Que.
H1P 2W7

Attn: M. G. Charbonneau
Directeur general

Eastern Refrgn. Supply Co. Ltd.
49 Riviera Drive
Markham, Ontario
L3R 5J6

Attn: Mr. David Merkel
V.P. Operations

Kerr Controls Ltd.
P.O. Box 1500
Truro, N.S.
B2N 5V2

Attn: Mr. A. H. Keirstead
Vice President

Master Refrigeration Ltd.
2555 Place Chasse
Montreal, Que
H1Y 2C3

Attn: M. Guy Forget
President

Climaref Div. de Westburne
8487-19e avenue
Montreal, Que.
H1Z 4J2

Attn: Mme Sylvie Complaisance
Superviseur Compt.

Carrier Canada Ltd.
Meadowvale Atrium
1900 Minnesota Court, Ste. 200
Mississauga, Ontario
L5N 5R5

Attn: Mr. Duncan Cochrane
Technical Support Mgr

Frontier
Div. Westburne Ind. Entr. Ltd.
5491 Timberlea Blvd.
Mississauga, Ontario
L4W 2T6

Attn: Mr. D. J. Dungale
General Manager

APPENDIX 2: DOMESTIC REFRIGERATORS AND FREEZERS

Sears Canada Inc., Dept. 731A, 2200 Islington Avenue, Rexdale, Ontario M9W 3W5

Contact: A. W. Wayne McKay, Technical support manager (416) 747-4708
Leo Zarins, Service Engineer, Technical Instructor, Consultant (Retired) (416) 463-6104

Business: Do not manufacture (rely on Camco, W. C. Woods, WCI

Largest service sector in Canada

- 42 main depots, 67 separate locations in every province (but not yet in Yukon/NWT)
- 1500 service locations across Canada

Provide training centre for servicemen in Toronto and Montreal (do not use CEASA training program)

Use wholesalers for purchase of CFC (i.e. Frontier/Altemp)

CFC Used in Servicing:

- CFC 12 and HCFC 22 (for air conditioning) approximately 16 tonnes/year in Canada, which could be recoverable
- Less than 1% of calls are to empty refrigerator units
- Find leaks normally in 4 places at connectors
- For 1000 service calls, 30 are CFC related, i.e. cracked liner (foam in place problem), defrost controls, heaters
- Higher frequency of service in summer months
- Some air conditioning servicing may be done outside in wind and rain
- Average life of freezer is 20 years
- They do not accept back scrapped goods
- Also use Freon TF for degreasing in shop in Toronto, 600 kg/yr
- Pressure test units with N_2
- Working on developing own recovery system (vacuum pump system with discharge into bag)
- Presenting use sweep charging to fill system ($\therefore$ use 10 oz to fill 6 oz system, with 4 oz discharged to atmosphere)

Inglis Limited, Administration Centre, 1901 Minnesota Court Mississauga, Ontario L5N 3A7

Contact: Albert McKillop, Director Customer Service (416) 858-4595
A. Pichler, Director Manufacturing (416) 366-7451

Business: Manufacture refrigerators and provide service to units
23 branches across Canada

Manufacture Related Information:

- Make 500 refrigerators/day (capacity is 1200 per shift)
- Whole North American market seems soft
- Biggest area of sales is replacement market, no export
- 15-20 years is expected lifetime

Foam in Place:

- Suspect lose ≈ 2% of CFC in blowing foam; use H_2O, polyol + CFC 11
- ≈ 20% of foam is CFC; 5.4 lbs foam per refrigerator
- Foam is blown into PE film laminated to styrene and foam is an integral part of unit strength of refrigerator wall

Testing:

- Use the purge to test system - first to use in North America
- Have own reclaiming system soon to be adapted
- Collect ≈ 100 oz/day to failed systems, ~ 6 oz/unit ($\therefore$ 16.7 net/day ≈ 0.03%)

Service:

- Have 23 direct factory branches across Canada
- Purchased 50 recovery tanks to store CFC; may be reusing CFC on-site, once it is collected
- Use Whirlpool/Inglis bag system to recover CFC from serviced units (see attached news release)
- Are interested in "Blue Bottle™" system for several reasons:
  - (1) Recognize bag could be bulky
  - (2) Recognize bag could be punctured
  - (3) Difficult to use under windy/stormy conditions
- They estimated 2000 system repairs a year, of which less than 2% of all service calls are CFC related (i.e. one every two days)

FOR MORE INFORMATION CONTACT:

MICHAEL THIENEMAN
INGLIS LIMITED
(416) 821-6625

FACT SHEET
CFC RECOVERY BAG

Inglis Limited's Canada-wide network of factory and authorized independent service centres will be using a specialized plastic bag to capture refrigerants containing chlorofluorocarbons(CFCs) when repairing sealed systems for refrigerators or freezers. The bag was developed by Whirlpool Corporation. It is designed to capture R-12, the type of CFC used in refrigerators and freezers. Chief characteristics of the bag include:

Tough and durable. The seven-layer plastic is highly puncture resistant.

Light and easy to transport. It comes folded in a small cardboard box. When opened, it measures 3 feet x 4 feet.

Reusable. It has a 28 oz. capacity that allows refrigerants from as many as three appliances to be captured in the bag before it must be emptied. The bag may be filled and emptied up to four times before being discarded.

Easily disposed of without contamination. Bags will be cut up to prevent their reuse in an inappropriate manner and then discarded with other waste plastics.

Inexpensive. It does not require a large initial investment by the servicing dealer or repair shop.

Easy and quick to use. Little or no additional time is required in the consumer's home during the repair process, and the very simplicity of the operation will encourage service technicians to use them.

Clean and neat. There is no mess and no heavy equipment has to be dragged through a consumer's home.

Capturing the used refrigerant in the CFC recovery bag while in a customer's home is only the first step in the recovery process. After it is full, the bag is taken to a recovery centre, usually the service centre repair shop, where the refrigerant is pumped into a pressured tank and saved for recycling.

Patents are pending.

WCI Canada Inc., P.O. Box 210, 18 Admiral Place, Guelph, Ontario N1H 6K2

Contact: Chris Kutter, Material Sales Manager (519) 767-4512
Don Good, Field Service Manager (519) 822-2188
Tim Burt, National Training and Quality Assurance Supervisor (519) 822-2188
Don Koehler, Manager Service Engineering and Training, Parts & Service Division, 6000 Perimeter Drive, Dublin, OH, U.S.A. 43017 (614) 792-4616

Business: Manufacture major appliances in Canada and U.S.A.
- Dishwashers, Dryers, Refrigerators and Air Conditioners

Use independent servicers across North America.
26 U.S. branches with 9000 independent servicemen (2/3 of whom do less than 50 calls with WCI - they do calls with other companies also. 650 depots across Canada.

CFC Interest:

- WCI came to ORTECH for a demonstration of the Blue Bottle™ use on Thursday, August 23, 1990.
- WCI Canada and U.S. are exploring mechanisms to capture CFC released in service of refrigerators. They have looked at the following capture systems already:
  - Inglis Whirlpool bag
  - AEG activated carbon bottle/cannister from Germany (18" long x 1.5" diameter, holds 1 charge)
  - Pump down system which is being developed in-house (not fully developed yet, but following specs were given: 1 ft^3/35-40 lbs pump with filters and condensers; pumped into 9 lb cylinders which can then be transferred to larger cylinder at depot
  - Other commercial pump down systems, but have dismissed them because of large size
  - Rubber bladder system used by Electrolux in Sweden
- The primary interest of WCI is the compliance aspect but they want a system with the following characteristics:
  (1) Low cost of use, i.e. $20 may be O>K>, $30-35 is probably too high (Inglis bag costs ~$21, used 3X - $7 per use

(2) Low maintenance aspects - they do not want to be in the business of recycling; recovery is their main concern
(3) A multi-use system (i.e. Inglis bag can be used 3X); their pump down systems enable them to use canisters over and over
(4) Lightweight system
(5) Ease of hook-up; do not want to carry a lot of extra baggage and want to use equipment that they would normally carry
(6) A fast withdrawal system
(7) Good assured capture with low ability for misuse (i.e. Inglis bag could be punctured and CFC released)
(8) For future reference, they would like to utilize a system where purified CFC can be purchased back from the recycler. This is important when allocations of CFC come into play.

- WCI was interested in various aspects of Blue Bottle™:

(1) The prospect of very low emissions
(2) Recovery only aspect
(3) Ease of hook-up; could be used with vacuum pump that they already use to pump down systems even further if required (activated carbon system cannot be used with vacuum pump at end of canister because the small carbon particles will enter the pump)
(4) Relatively lightweight
(5) Relatively fast procedure
(6) They did pilot with Inglis system and technicians did not like using it
(7) Can be used with replacement CFCs

- The following concerns about the system arose:

(1) How does the technician know that the system has been emptied completely (i.e. servicemen need to be told to leave it on for X minutes)?
(2) Canisters need to be marked full or empty (otherwise could be weighed)
(3) System use needs to be kept around $20 - any higher and it would be cheaper for them to use Inglis bag or their own system
(4) Can the canisters be owned by WCI (or servicemen) and the proprietary molecular sieve be taken in and out of the canisters via a filter bag? These filter bags could be kept in storage on site in boxes until volume is large enough to warrant transport to recovery operation

(5) What is cost breakdown for different Blue Bottle™ use scenarios, i.e. (a) WCI buys canisters, rents Blue Bottles; (b) WCI rents canisters and Blue Bottles?

(6) Is Union Carbide in U.S.A. willing to set up system so that market can be serviced too? (U.S.A. market ~ 100,000 lbs CFC discharged per year; Canadian market ~ 10,000 lbs CFC discharged per year [AHAM estimates]

- WCI indicated they would like to conduct field trials with the Blue Bottle™ in both Canada and U.S.A. WCI is working on the Environmental Committee of CEASA and suggested that, if they approve of the system, then the other companies would likely adopt the system as well.

  The refrigerator repair companies and manufacturers share many of their independent service technicians and a common solution would be the best for all involved. A meeting between CSA, Environment Canada and CEASA will take place on September 7, 1990, to start developing standards for purified refrigerant. WCI would like to talk to Linde about the Blue Bottle™ before this date.

Other Notes of Interest

- WCI uses a variety of independent technicians who act as servicemen for many of the industries. Therefore, it is beneficial for all companies to adopt a common system
- WCI indicated that an individual serviceman can be dedicated to full system repairs and might do 2-3 refrigerators per man per day. They distinguish between warranty (1-5 years) related calls and after warranty servicing

Warranty Period:	~ $119 cost for WCI for sealed system repair Estimate 2% of all calls under warranty require CFC removal
After Warranty Period	~ $200 cost for sealed system repair Estimate 1% of all calls out of warranty period would require CFC removal

∴ Estimate 14,000 service calls in 1 month (Canada)
2% under warranty for CFC discharge gives
280 calls/month
(in U.S.A. ~ 2,800 calls/month requiring CFC discharge)

AHAM estimates: 100,000 lbs of CFC discharged/year in servicing in U.S.A.
10,000 lbs of CFC discharged/year in servicing in Canada

W. C. Woods Company Ltd., 5 Arthur St. S., Guelph, Ontario N1H 6L9

Contact: John Atkinson, Manufacturing Engineer
Steven Griffin, Manager, Product Engineering
(519) 821-0900

Business: Manufacture freezers (chest and upright), dehumidifiers and refrigerators

Second largest in North America for volume of sales

Manufacture for GE (in US and Canada), Admiral, Sears/Kenmore, Whirlpool

No service side/not factory owned - depend on independent contractors across North America. Do service items that come back from appliance stores

Make 80/hr average, 8.5 hr day, 40 hr week/Sell over 1/2 to USA

Recycled CFC Purity Concerns:

- Leery about Vampire systems recovery and reuse of used CFC
- Developing and evaluating own system for rejected goods on-site
- Want to capture/stockpile, then sell back to DuPont/Allied for reprocessing
- Concern that compressor changes to suit substitutes should be done only once - not with every new substitute as it comes out - conversion expensive

CFC 11 Foam in Place Concerns:

- CFC 11 - no isolation of foaming system, loss in manufacture 0-15%
- Concern that substitutes still give high R value to meet energy consumption requirements

Refrigerant Reclamation On Site:

- Reclaim 600 kg (1 tonne/year) with recovery system which they built. (Have taken extra precautions with 2 oil traps; have 4 units total for all plants
- 1.3% of product line is reject
- 1-2 minutes to drain 6-10 oz freezers
- Also have small service department for material coming back from appliance stores use that reclaims dirtier refrigerant isolated. Strip appliance for recycling and recycle as much as possible

Foam in Place:

- Could recover approximately 10 tonnes/year (3 g lost lb foam 1.5 x make x 1 million lbs foam/year
- One line has 2 breather holes for recapture of CFC 11
- Have cut back 30% of CFC 11 use in foam already
- 20% stays in foam
- In board manufacture, there are no breather holes - CFC leaks out of all edges until set
- High volume of air required to exhaust CFC and isocyanate from work environment - ≈ 10,000 CFM with no idea of CFC concentration in air

Appliance Testing Area:

- Evacuate system for 9.5 mins
- Test for evacuation
- CFC 12 charge applied (with shut off valve lose only minimal amount)
- Leak testing concentration varies daily, depending on background
- Leak area checked and sealed off - solder area
- Test area, after welding at all joints, with mass spec detectors
- Testing people must be trained and go through certification program

Ottawa Recycle Appliance Store, 2487 Kaladar, Ottawa, Ontario K1V 9A9

Contact:	Gord Anderson (613) 731-1417
Business:	Not for profit charitable organization has contract with Region of Ottawa Carlton to pick up all white goods from households discarding Are in the business of repairing and reselling suitable appliances and recycle as much of the component parts as possible Twenty people work full-time - also have store component where appliance is sold to welfare homes Collect 7-10,000 appliances per year (1/2 to 1/3 are refrigerators, ~ 4-5 freezers/week)

CFC Interests:

- Recover CFC before service or discharge with homemade apparatus
- Use old compressor and fridge to contain CFC canister
- Have collected ~ 100 kg of CFC in past few months and are storing it until they can get rid of it (i.e. also would like to get paid for it)

Environmental Applications Group (EAG), Suite 1006
20 Eglinton Avenue West, P.O. Box 2041
Toronto, Ontario M4R 1K8

Contact: Dimitri Stone, Principal Scientist, Aquatic Studies
Richard Kolomeychuck, Principal, Physical Sciences
(416) 322-5701

Business: Environmental consulting firm with major interest in CFC recovery from scrapped domestic and commercial refrigeration equipment

Has partnership with AVIV, an R & D consulting group in the Netherlands which has developed a system for CFC recovery now in use in the Netherlands

CFC system can be:

(1) mobile unit which has hydraulic hoisting system, sealed drill head and extractor, oil/gas separator, compressor with recyclable storage vessels. System can evacuate a refrigerator in 90 secs (excluding placement of refrigerator on hoist

(2) Fixed facility to which units can be brought to. This set up includes a conveyer system and a similar extraction system as used in the mobile set up. This facility also includes a dismantling line where appliances are completely dismantled into components for selective recovery, i.e. copper, aluminum scrap and steel, with further separation of scrap fluff as desired

Mobile unit in Friesland has processed over 40,000 refrigerators

Can run 15-20/hr

Have also looked at large commercial coolers

Are also evaluating CFC recovery from insulation foam as well as destruction technologies

Have submitted proposals to the MOE and City of Toronto to conduct pilot program for curbside pick up which could include a series of small depots

City of Toronto estimates 25-30 refrigerators/week curbside disposal. Other large sources are expected from appliance repair stores, jobbers, stores who take back off spec products

Has discussed this proposal with most of the Metro area representatives

Intermetco, The International Metals Reclamation Group Inc., Metals Recycling Division, 595 Commissioners Road Toronto, Ontario M4M 1A5

Contact: John Kis, General Manager (416) 469-5500

Business: Intermetco is one of Canada's largest scrap steel processors

Previous concerns have been with contaminated scrap, i.e. oils, PCBs, that can cause problems "shredder fluff" from their processing

Most of the materials they receive have already been processed and stripped by local scrap dealers who compact and crush the materials for transport to them.

CRC Interests:

- Intermetco apparently does not want to get into the business of CFC recovery from scrap goods as they do not foresee much CFC left in the equipment when they receive it, either in automobiles or appliances

Institute of Scrap Recycling Industries Inc. (ISRI)
1627 King Street NW, Washington DC

Contact: (202) 466-4050

Business: Industry association representing scrap recyclers, more prominent in the USA

CFC Related Comments:

- Have issued a policy statement entitled "Design for Recycling" which promotes the design and manufacture of appliances, automobiles and other consumer goods for sale and efficient recycling at the end of their useful lives. This policy incorporates CFC issues by suggesting that items containing CFC should be designed so that CFC reclamation can be done prior to recycling and/or disposal. The Institute also declared that legislation should not attempt to mandate recovery of emissions from CFC blown foam because, currently, it is neither technically or economically feasible

Appliance Industry-Government CFC Replacement Consortium (USA)

Founding Members Include: Amana Refrigeration, G.E., Maytag Corp., Whilpool Corp. and White Consolidated Industries. Government representatives include: Department of Energy and Environmental Protection Agency

- Will analyze design options and conduct research into replacements for CFC 11 and 12.
- Will work cooperatively with compressor suppliers and other component manufacturers

Canadian Appliance Manufacturers Association (CAMA)
10 Carlson Court, Rexdale, Ontario

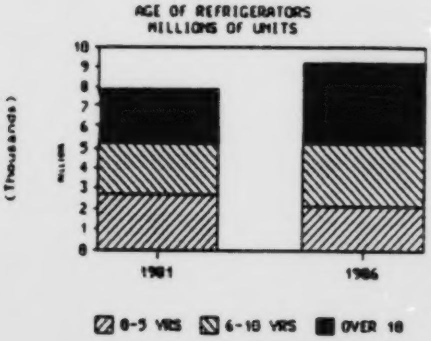
Contact: Norm Aspen (416) 674-7410

Business: Have supplied manufacturing data on refrigerators/freezers/air conditioners in the domestic market (see attached)

AGE OF REFRIGERATORS IN USE (000 Units)*

	1981		1986	
	Units	%	Units	%
0 - 5 Years	2765	34.6	2214	23.9
6 - 10 Years	2462	30.9	3050	32.9
Over 10 Years	2752	34.5	3998	43.2
Total	7979	100.0	9262	100.0

Source: Statistics Canada #64-202
*1987 Data Unavailable



In five years, the stock of Refrigerators in use has grown from 8.0 million units in 1981 to 9.3 million units in 1986, an increase of 1.3 million units. The number in use over ten years of age increased by 1.2 million units from 2.8 million to 4.0 million. The potential replacement market is growing.

REFRIGERATORS

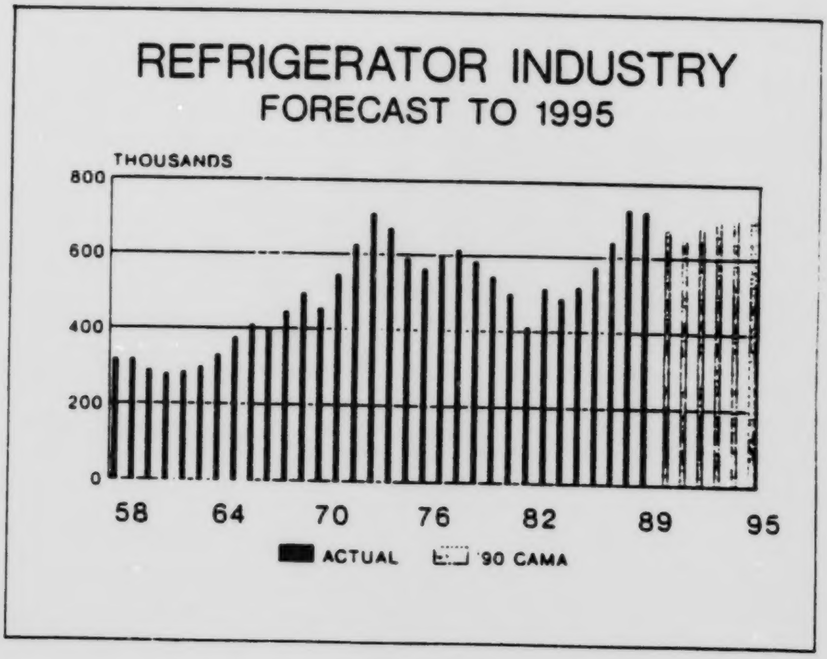
In 1989 Refrigerators experienced another strong year but a slight decline (0.7%) from 1988. Imported Refrigerators continue to play a key role in this industry.

1990 will bring a softening in the order of 7.3% to the Refrigerator industry and return it to 1987 levels. This softening is a direct result of declining housing activity, higher interest rates and weakening consumer confidence.

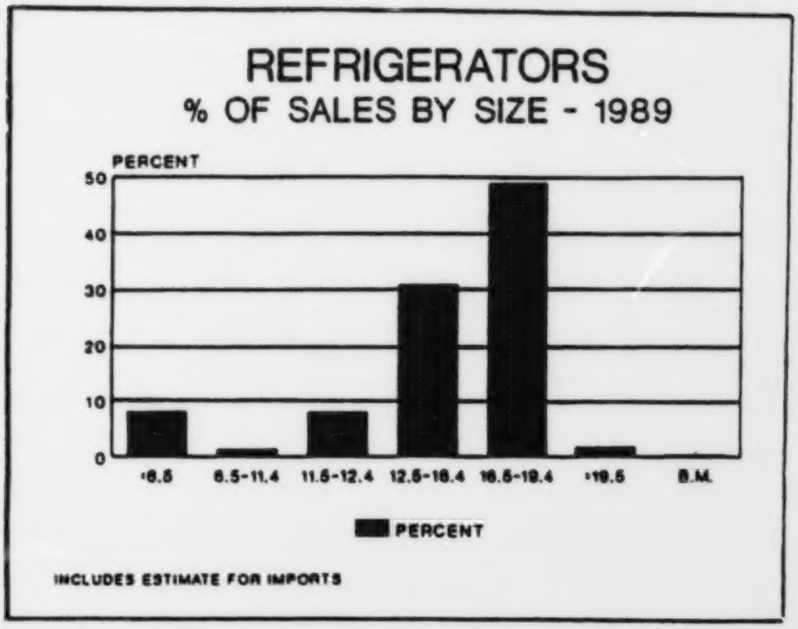
Five-Year Forecast
(000 Units)

	Actual					Forecast					
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Retail-Regular	382	408	461	506	534	500	510	530	550	570	580
Retail-Compact	53	70	70	102	50	50	50	50	50	50	50
Retail-Total	435	478	531	608	584	550	560	580	600	620	630
Builder	85	97	111	121	140	125	100	100	100	100	100
Total	520	575	642	*729	724	675	660	680	700	720	730
% Change	6.3	10.6	11.7	13.6	(0.7)	(7.3)	(2.3)	3.0	3.0	2.9	1.4

*Actual 1988 data revised for change in import assumptions



BY SIZE



REFRIGERATORS

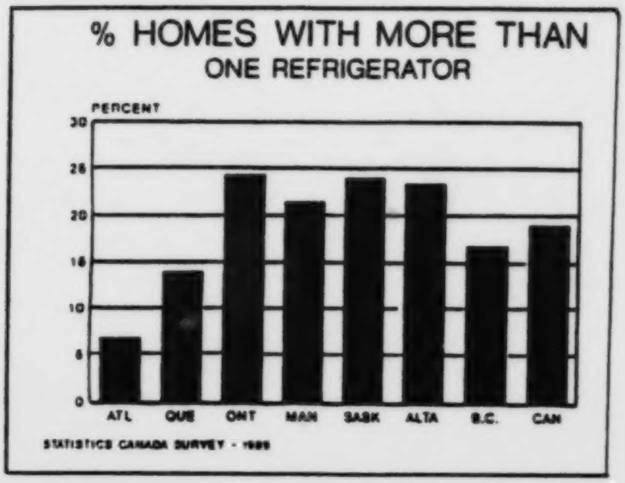
% OF SALES BY SIZE - 1989

INCLUDES ESTIMATE FOR IMPORTS

SATURATION (% OF TOTAL HOUSEHOLDS)

	With At Least One Refrigerator		Homes With More Than One Refrigerator
	1984	1989	1989
Atlantic	99.0	99.5	6.8
Quebec	99.7	99.0	13.9
Ontario	99.6	99.7	24.3
Manitoba	99.7	99.0	21.4
Saskatchewan	99.7	99.7	24.0
Alberta	99.6	99.5	23.4
British Columbia	99.7	99.5	16.7
Total Canada	99.6	99.4	19.0
Total Households(000)	8.857	9.477	9.477

Source: Statistics Canada #64-202
1989



1989 up 0.2% from 1988 nationally.

IMPORTS

	Household Refrigerators			Other Absorption Type (not included in total imports)	
	Import Units	Import $ (000)	% of Total	Import Units	Import $ (000)
1984	83,980	22,320	17.2	19,913	6,379
1985	79,065	22,439	15.2	21,746	7,534
1986	107,428	28,175	18.7	20,869	8,738
1987	143,276	47,540	22.3	20,570	8,497
1988	209,344	63,955	28.7	13,423	4,148
1989*	121,560	60,613	19.6	4,648	967
1989**	150,000				

*October 1989 year-to-date.
** 1989 year end estimate based on October year-to-date figures.

Source: Statistics Canada #65-007

EXPORTS

	1987	1988	1989
Exports (Units)	27,176	28,716	13,284*

*October 1989 year-to-date.

Source: Statistics Canada #43-010

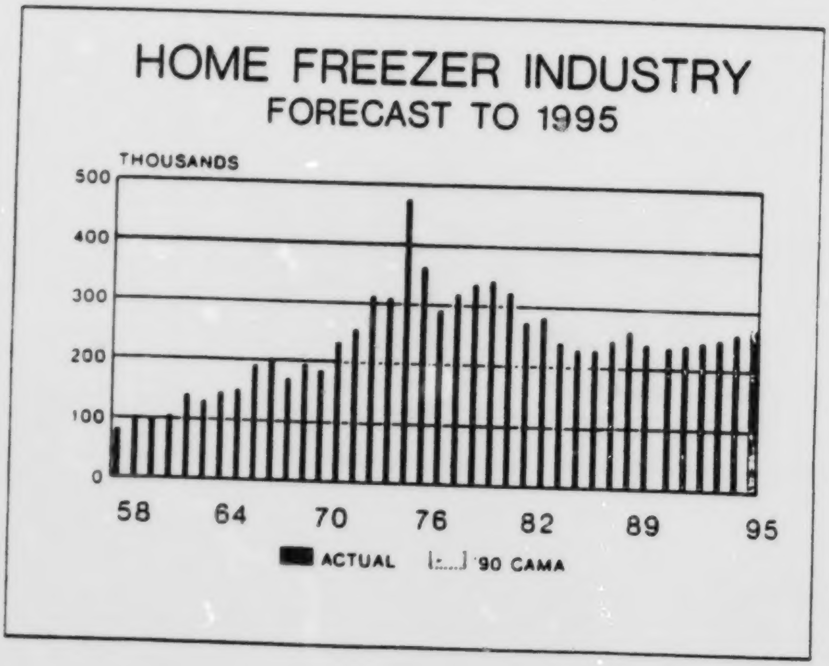
FREEZERS

Sales of Freezers declined in 1989 to 240,000 units. This level of sales is much more typical of this product than last year's unexpected peak of 261,000 units.

Freezer sales should remain fairly consistent until 1994 when the Committee forecasts significant growth through to 1995.

Five-Year Forecast
(000 Units)

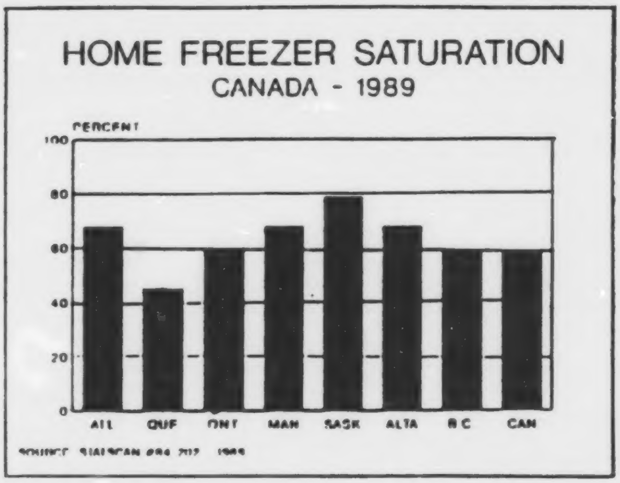
	Actual					Forecast					
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
FREEZERS	229	229	245	261	240	235	240	245	250	260	270
% Change	(4.6)	-	7.0	6.5	(8.8)	(2.1)	2.1	2.1	2.0	4.0	3.9



SATURATION (% OF TOTAL HOUSEHOLDS)

	1984	1989
Atlantic	62.8	67.6
Quebec	42.6	45.4
Ontario	57.1	59.8
Manitoba	68.1	67.9
Saskatchewan	77.7	78.8
Alberta	64.6	67.9
British Columbia	60.0	59.0
Total Canada	56.1	58.3
Total Households (000)	8,857	9,477

Source: Statistics Canada #64-202
1989



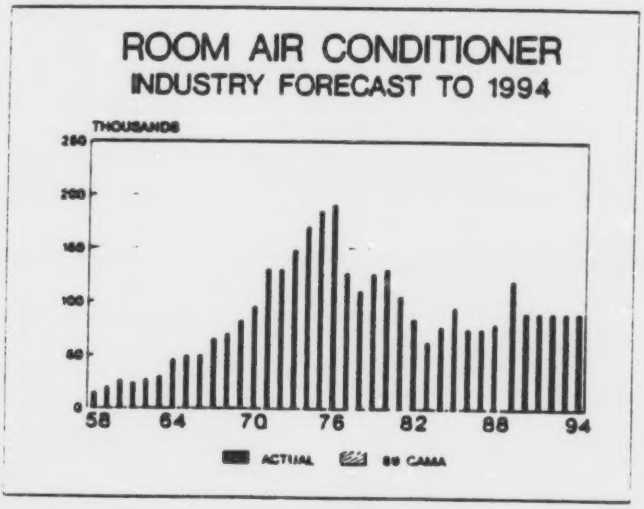
1989 up 1.4% from 1988 nationally.

ROOM AIR CONDITIONERS

This year is expected to be the last year CAMA will report on the Air Conditioner market, as CAMA no longer has a reporting member in the business.

Five-Year Forecast (000 Units)

	Actual					Forecast					
	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Room Air Conditioners	77	95	75	75	80	120	90	90	90	90	90
% Change	22.2	23.4	(21.1)	-	6.7	50.0	(25.0)	-	-	-	-



Generally the Air Conditioner market since 1981 has been buoyant as a result of the recent years' summer heat waves.

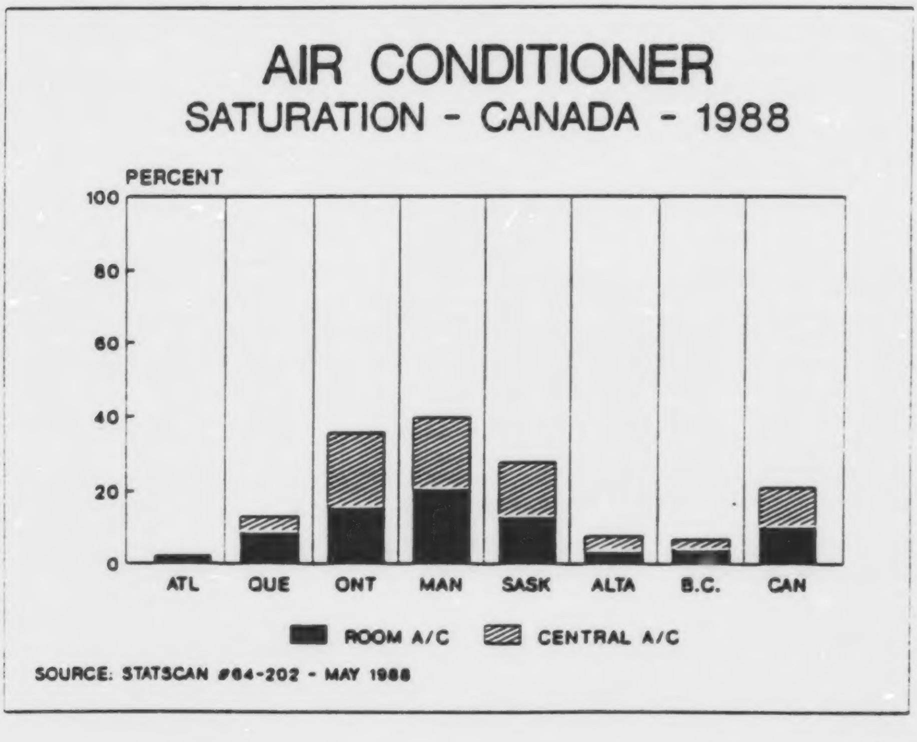
The market will experience some growth in 1989 as people anticipate another hot summer.

SATURATION (% OF TOTAL HOUSEHOLDS)

	1983	1987	1988
Atlantic	2.5	1.5	2.0
Quebec	9.0	8.9	8.5
Ontario	15.0	14.4	15.3
Manitoba	14.7	18.9	20.3
Saskatchewan	9.0	13.2	12.8
Alberta	3.1	4.1	3.1
British Columbia	4.9	3.7	3.8
Total Canada	10.0	9.8	10.0
Total Households (000)	8,460	9,082	9,244

Source: Statistics Canada #64-202
May 1988

Saturation levels are greatest in Manitoba and Ontario and lowest in the Atlantic Provinces.



SOURCE: STATSCAN #64-202 - MAY 1988

COMPARISON WITH
U.S. MARKET

MAJOR APPLIANCE INDUSTRY SALES
(000 UNITS)
CANADA versus U.S.A.

YEAR	CANADA	PER CENT YEAR-TO-YEAR CHANGE	U.S.A. *	PER CENT YEAR-TO-YEAR CHANGE
1988	3,899	(1.1)	42,101	(0.9)
1987	3,947	6.2	42,470	6.0
1986	3,715	14.9	40,055	8.5
1985	3,232	14.5	36,927	6.8
1984	2,822	4.8	34,586	22.1
1983	2,694	22.8	28,328	21.5
1982	2,193	(15.4)	23,315	(12.3)
1981	2,593	(8.0)	26,576	0.4
1980	2,820	(2.0)	26,460	(8.6)
1979	2,878	(0.8)	28,949	(0.7)
1978	2,901	3.5	29,161	6.3

*U.S.A. data includes export shipments.

MAJOR APPLIANCE PRODUCTS

Refrigerators
Home Freezers
Ranges (Electric)
Clothes Washers (Automatic)
Automatic Dryers (Electric and Gas)
Dishwashers
Room Air Conditioners
Microwave Ovens

DATA SOURCE: Canada - Canadian Appliance Manufacturers Association (CAMA)
U.S.A. - Association of Home Appliance Manufacturers (AHAM)

Canadian Electronic & Appliance Service Association (CEASA)
Ste 115, 10 Wynford Heights Crescent, Don Mills, Ontario M3C 1K8

Contact: Ken Allen (416) 447-2511

- Organization of appliance servicemen including WCI, Sears, Inglis, Camco, The Bay, T. Eaton Co. and various electronics equipment manufacturers
- Run (CEASA) training courses 2 x year in major cities across Canada which technicians can take to obtain a "Certificate of Achievement"
- Estimate approximately 2400 servicemen in CEASA from member organizations plus another 2000 servicemen that are not members and operate as independents

- This figure compares well with statistics from USA AHAM where USA estimates the following: (AHAM Sources)

# of Servicemen		# Major Appliance Sales
USA (1988)	40,000	42,101,000
Canada		3,899,000
est. ≈ 10% of U.S. figure	4,000	
est from CEASA	4,400	

- Therefore, from table we can estimate that Canadian figures are 10% of U.S. figures
- Are looking for a national approach to CFC recovery/recycle because they are a national organization
- Have just recently formed an environmental working group to address CFC issues (re servicing)

Equipment Manufacturers Association of Canada (EMAC)
10 Carlson Court, Rexdale, Ontario

Contact: Alda Murphy, Manager Appliance Group (416) 674-7410

- Includes major appliance manufacturers of home appliances, i.e. Inglis, G.E., WCI, General Freezer, W. C. Wood
- Planning mini conferences for membership

Association of Home Appliance Manufacturers (AHAM), U.S.A.

Contact: Marion Stamos

Membership Includes: W. C. Woods, Amana, WCI, Whirlpool, Admiral, G.E., Subzero, Department of Energy, EPA

- CFC consortium interested in phase out of CFCs
- Will analyze design options and conduct research into replacements for CFC 11 (blowing) and 12 (refrigeration)
- Will work cooperatively with compressor suppliers and other component manufacturers
- Example of pilot research project:
    - W. C. Woods (Guelph, Ontario) testing new HCFC that is flammable and testing various replacements for CFC 11
- Estimates 40,000 independent servicemen in U.S.A. (can estimated 10:1 for Canada)
- Systems have most of work done in first 5 years (life of warranty)
- Estimate 2% of calls in warranty period need CFC discharge and 1% after warranty period
- Each serviceman may have 6-12 sealed system service calls/year
- Average refrigerator lasts 17 years
- Average freezer lasts 21 years
- Total quantity of CFC available from servicing domestic refrigerators/freezers ~ 100,000 lbs U.S.A.
  ~ 10,000 lbs Canada
  (see calculation samples as attached)
- "AHAM's recommendations to U.S. EPA include:
    - Proposes a public awareness campaign for consumers and servicers that explains the ozone-depleting potential of CFC 12 and encourages proper capture procedures during in-home servicing and effective disposal practices in their locality.
    - Recommends EPA identify the most effective program for capturing CFC 12 at disposal. This avenue offers the greatest opportunity for capturing the refrigerant - up to as much as 34 times the total that is expected from in-home capture in one year.
    - Supports off-site recycling/reclamation of CFC 12 because current on-site equipment technology is very expensive, does not attain the purity level needed for servicing sealed home refrigeration systems, and is too heavy for portability into most kitchens.

- Supports EPA's intention to recycle/reclaim captured CFC 12 and affirms the Association's willingness to cooperate with CFC producers and other recyclers to meet EPA's objective, but notes the limitations of appliance manufacturers, who are not recyclers; and
- Argues against EPA's recommendation for regulating CFC emissions during appliance manufacture, primarily because of the strong incentive to frugally use the increasingly expensive CFC supply."

CFC TF 2/7/90 Mtg.
Minutes -- Attachment 4

ESTIMATED LBS OF CFC 12
CAPTURED DURING PRODUCT SERVICE

(1) Service Calls on Sealed Systems/Year x Non-leak % (.75) x # Units = Maximum for capture at service

(2) Maximum Available for Capture x Yield % (.80) = Pounds captured annually

Scenario (Low Range)

(1) 0/5 year - 160,000 x .75 x 6/16 = 45,000
6/17 year - 80,000 x .75 x 9/16 = 34,000
TOTAL 240,000 = 79,000 Available

(2) 79,000 x .8 = 63,000 Pound Captured Annually

Scenario (High Range)

(1) 1/5 year - 160,000 x .75 x 6/16 = 45,000
6/17 year - 240,000 x .75 x 9/16 = 10,000
TOTAL 400,000 = 146,000 Available

(2) 146,000 x .8 = 118,000 Pounds Captured Annually

CFC TF 2/7/90 Mtg.
Minutes -- Attachment 5

ESTIMATED LBS OF CFC 12
CAPTURED DURING PRODUCT DISPOSAL

(A) Assume 9/16 # Per Unit (R-12)

(B) Assume 6.4 Units Disposed Annually

(C) Assume 80% Still Have Charge

(D) Assume A x B x C = Pounds Available for Capture

(E) Assume 80% Yield at Capture

D x E = Pounds Captured /2,304,000 #/

APPENDIX 3: MOBILE AIR CONDITIONING

Chrysler Canada, 2545 Chrysler Centre, Windsor, Ontario N9A 4H6

Contact: Fred Daws, Manager Materials Engineer & Lab Engineer Staff
Paul Hansen, Environmental Coordinator, Facilities Engineering
(Contacted by C. Karayannopoulos, D. Filipovich, Linde Canada)

Business: Manufacture automobiles and supply service

Trip Report: From C. Karakyannopoulos, Linde

Purpose:

To obtain information on Chrysler's CFC activities and to inform them about our CFC recovery process under development

Conclusions:

Fred Daws was favourably impressed with our concept and would like to test a pilot unit at the Windsor plant, upon consultation with his counterparts in the U.S.

Details:

Chrysler have been testing a PCU freon recycling unit (liquid transfer). They feel it is superior to the Rondair unit (GM's choice), but there are still problems with it. Some of the points raised were:

- They see problems with the recycling capabilities of these liquid transfer units, because the process is small scale and requires dedicated expertise to operate it. This would present considerable difficulties for the smaller dealerships.
- They would much prefer to access a central recycling facility. They would not mind receiving recycled freons either from DuPont or a recycling outfit, provided the freon met their specs. They liked our idea of a collection network with a central recovery/purification facility.
- The problem of fugitive emissions at the plant level has not been addressed yet. They saw our process as a perfect fit for that problem. Chrysler-Windsor consume about 350 tonnes of Freon 12/year. Average consumption is 1-2 kg/car.
- At the plant level, leaks occur when the storage tanks are filled/vented and when individual car units are filled up.

- The first non-CFC air conditioned car should be mass-produced by 1994, using HCFC 134a. The cost of this alternative is not known; it is expected that it will be several times (even an order of magnitude) more expensive than Freon-12.
- Fred Daws will get back to us with the specs on recycled Freons, recently adopted in the U.S.

Ford Motor Company of Canada Ltd., Public Affairs Office, The Canadian Road, Oakville, Ontario L6J 5F4

Contact: Jim Hartford, Public Affairs Office, (416) 845-2511 ext. 1316

Business: Automobile manufacture, sale and service

CFC Interests:

- Ford had announced on October 16, 1989, to make CFC recycling equipment available to Ford and 681 Lincoln-Mercury dealers across Canada to capture CFC 12 in automotive air conditioning systems source. Dealers could buy any Underwriters Laboratories (UL) approved system, but Ford Canada will make its Rotunda model available in Canada.
- Recycling incentive will be economic - warranty reimbursements to dealers for recycled CFC will be paid at the same rate as new refrigerant.

Motor Vehicle Manufacturers Association (MVMA)
25 Adelaide St. East, Suite 1602, Toronto, Ontario M5C 1Y7

Contact: From Presentation at Sharing Options for Ozone Protection, November 30, 1989, Toronto (416) 364-9333

Member Companies: Chrysler Canada Ltd., Ford Motor Company of Canada Ltd., Mack Truck Inc., Nawstar International Corp Canada, Paccar of Canada Ltd., Volvo of Canada Ltd., Western Star Trucks Inc.

- Directly employ approximately 140,000 people in Canada
- Production of 1.6 million units, of which 1.3 million exported to U.S.

CFC Interests:

- Support Montreal Protocol and CFC reduction initiates
- Member companies are committed to complete phase out of CFCs in new motor vehicle air conditioning by mid 1990
- CFC 11 used in foam blowing for flexible foam seat pads and other interior safety-related energy absorbing materials. Water foam blowing process needs to be further improved to obtain standards required for foam density energy management, during collisions
- CFC 113 used in degreasing parts do have substitutes available
- CFC 113 used in cleaning electronic circuit boards for emissions and engine controls. Will probably practice conservations in the interim until good substitutes are found
- CFC 12 used in mobile air conditioning. It is estimated 30-40% of cars sold in Canada have air conditioning - in 1987 - just over 1 million cars sold (in U.S. 90% of passenger cars have air conditioning, therefore our market is probably growing). No drop in replacements - 22 has technical problems with lubricants, hoses and seals, and 134a is not yet commercially available. Member companies do support Recovery and Recycling initiatives at the plant site and at service level.
- Have endorsed standard of purity for use in mobile air conditioning systems (see attached)
- The major manufacturers are also a part of the Mobile Air Conditioning Society

Certification Training Manual

CFC-12 Refrigerant Recycling & Service Procedures

For Automotive Air Conditioning Technicians

TITLE:
CFC-12
Certification Training Manual
Refrigerant Recycling
& Service Procedures
For Automotive Air Conditioning Technicians
© Mobile Air Conditioning Society, 1990

SAE J1989
Recommended Service Procedure for the Containment of R-12 (Pages 5-7)
© Society of Automotive Engineers, 1989

Containers: Handle With Care (Page 8)
© Murray Corporation, 1989

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The Purpose of this Manual
(A word to the service technician . . .)

Because of a worldwide consensus that chlorofluorocarbons (such as the CFC-12 used as refrigerant in mobile air conditioning systems) destroy the stratospheric ozone layer, this industry has moved with all possible speed to implement refrigerant recycling for use in automotive air conditioning repair.

Now it's all up to you!

If you fail to operate or maintain your refrigerant recycling equipment as required by the equipment manufacturer — the development of recycling technology will have been in vain.

You are the key to the success of refrigerant recycling, and a lot is riding on the success of the technology. Please take the time to read this manual completely and do your part to make it work.

Stratospheric Ozone Depletion and CFCs

THE ISSUE

Common practice in the service of mobile air conditioning systems has been to add refrigerant to a leaking system and vent the charge when other service was required. The practice was acceptable because refrigerant was relatively inexpensive and thought to be environmentally benign. But knowing what we do today about the role of R-12 in the degradation of the earth's protective ozone layer, such service practice is irresponsible and can no longer be condoned. Soon, such "service" will be illegal.

OVERVIEW

Stratospheric ozone acts as a shield against harmful solar ultraviolet (UV) radiation. A significant reduction in ozone in the upper atmosphere could result in long-term increases in skin cancer and cataracts, and probably damage the human immune system. Reductions in the abundance of stratospheric ozone could reduce crop yields and alter terrestrial and aquatic ecosystems.

A consensus has emerged worldwide that chlorine from synthetic chemicals called chlorofluorocarbons (CFCs) and bromine from chemicals called halons will deplete ozone in the stratosphere. CFCs are used as blowing agents in plastic foam products (cushioning, insulation and packaging), as refrigerants, as solvents, as sterilants and in aerosol applications. Halons are used as fire extinguishing agents. To protect the ozone layer, the United States, fifty other nations, and the European Economic Community ratified the Montreal Protocol on Substances that Deplete the Ozone Layer. This is a landmark international agreement designed to control the production and consumption of certain chlorofluorocarbon and halon compounds.

THE THEORY

Ozone is formed when oxygen molecules absorb part of the sun's ultraviolet radiation and split apart into two oxygen atoms. These separated atoms then combine with other oxygen molecules to form ozone, which contains a total of three oxygen atoms. Ozone itself is a pungent, slightly bluish gas — a close chemical cousin to molecular oxygen. About 90 percent of the earth's ozone is located in a natural layer far above the earth's surface in a frigid region of the atmosphere known as the stratosphere. This natural layer acts as a shield against ultraviolet radiation.

Concern about possible depletion of the ozone layer from CFCs was first raised in 1974 with publication of research which theorized that chlorine released from CFCs could migrate to the stratosphere and destroy ozone molecules. (Molina and Rowland, 1974). Some of the CFCs have an atmospheric lifetime of more than 120 years (i.e., they do not break down in the lower atmosphere). As a result, they migrate slowly to the stratosphere where higher energy radiation strikes them, releasing chlorine. Once freed, the chlorine acts as a catalyst repeatedly combining with and breaking apart ozone molecules.

If ozone depletion occurs, more UV radiation penetrates to the earth's surface. Moreover, because of the long atmospheric lifetimes of CFCs, it would take many decades for the ozone layer to return to past concentrations.

In the sixteen years since the theory was first proposed, substantial scientific research has supported the general concern that increased concentrations in the atmosphere of chlorine, as well as bromine from halons, pose substantial risks of ozone depletion resulting in harm to human health and the environment.

HEALTH & ENVIRONMENTAL EFFECTS

Shielding the earth from much of the damaging part of the sun's radiation, the ozone layer is a critical resource safeguarding life on this planet. Should the ozone layer be depleted, more of the sun's damaging rays would penetrate to the earth's surface. Each one percent depletion would increase exposure to damaging ultraviolet radiation by 1.5 to 2 percent.

The Environmental Protection Agency's (EPA) assessment of the risks from ozone depletion focused on the following areas:

- Increases in skin cancers
- Suppression of the human immune response system
- Increases in cataracts
- Damage to crops
- Damage to aquatic organisms
- Increases in ground level ozone
- Increased global warming

HUMAN HEALTH EFFECTS

Skin cancer is already a serious problem in the United States but would increase with further depletion of the ozone layer. Under current atmospheric conditions, the greater the distance from the equator, the greater the effectiveness of the ozone layer as a shield. As a result, there is a natural experiment taking pace. People who live further north are exposed to less damaging UV radiation than those residing closer to the equator. Not surprisingly, the chances of getting skin cancer follow the same gradient — the closer to the equator, the greater the risk from ultraviolet radiation.

Three distinct types of the skin cancer would increase if the ozone layer is depleted. Basal and squamous cell skin cancers are the two most common types, now affecting about 500,000 people annually in the United States. If detected early, these cancers are treatable. Even so, approximately 1 percent of cases result in premature deaths.

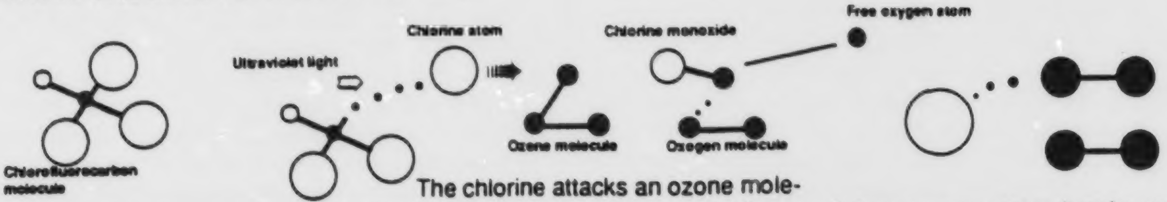
Malignant melanoma is far less common but substantially more harmful. About 25,000 cases now occur annually resulting in 5,000 deaths. While the relationship between exposure to UV radiation and melanoma is complex, existing studies provide a basis for estimating future risks associated with ozone depletion.

Cataracts cloud the lens of the eye, thus limiting vision. Although cataracts develop for a variety of reasons, scientific evidence supports the conclusion that increased exposure to UV radiation from ozone depletion would increase the number of people experiencing this eye disorder.

Based on epidemiological studies, if current trends in the use of ozone depleting gases continued, the number of cataract cases would increase by 18 million (for the population alive today or born before 2075). Actions required by the Montreal Protocol and EPA's Proposed Rule to limit the use of these chemicals would reduce the number of additional cases by 92 percent during this time period.

Suppression of the immune system is another possible threat to human health resulting from ozone depletion. Research to date suggests that exposure to UV radiation weakens the ability of the immune system to fend off certain diseases (i.e., herpes simplex and leishmaniasis,

HOW OZONE IS DESTROYED



In the upper atmosphere ultraviolet light breaks off a chlorine atom from a chlorofluorocarbon molecule.

The chlorine attacks an ozone molecule breaking it apart. An ordinary oxygen molecule and a molecule of chlorine monoxide are formed.

A free oxygen atom breaks up the chlorine monoxide. The chlorine is free to repeat the process.

a parasitic disease common in the tropics). However, more needs to be known about the exact way the immune system is affected and the implication UV radiation exposure has for a wide variety of other diseases.

PLANT & MARINE EFFECTS

Crops and other terrestrial ecosystems could also be adversely affected by increased exposure to UV radiation. In greenhouse studies, approximately two-thirds of the crops exposed to elevated levels of UV radiation proved sensitive. Field studies of soybeans have shown that ozone depletion of up to 25 percent could decrease yield by over 20 percent, with substantially greater reductions in years when climatic stresses were also a factor.

Certain marine organisms, particularly phytoplankton and the larvae of many species, may be sensitive to increased exposure to UV radiation because they spend much of their existence near the surface of the water. Although it is difficult to design experiments replicating aquatic environments, research to date suggests that adverse effects on productivity and species diversity are related to increased exposure to UV radiation.

Other Impacts:

- Ground Level Ozone — Ozone depletion would increase the rate of formation of ground level (tropospheric) ozone, a major component of what is commonly called smog.
- Degradation of Polymers — Ozone depletion would accelerate the weathering (i.e. chalking, yellowing, and cracking) of plastics used in outdoor applications.
- Climate Change — CFCs are greenhouse gases (i.e., have similar properties to carbon dioxide) and thus would contribute to global warming and rising sea levels.

GLOBAL PROBLEM

Unlike many other environmental issues, stratospheric ozone protection is truly a global problem. CFCs and halons are used in many nations. And given their long atmospheric lifetimes, they become widely dispersed over time. As a result, the release of these chemicals in one country could adversely affect the stratosphere above, and therefore the health and welfare of other countries. Many developed and some developing countries produce CFCs and halons. Most consume the chemicals in a variety of different products. The United States, for example, is one of the largest consumers of the world's CFCs. Other nations are also significant users.

Therefore, to protect the ozone layer from the damages that may be caused by CFCs and halons, an international solution is critical.

MONTREAL PROTOCOL

Recognizing the global nature of the problem, on September 16,1987, in Montreal, Canada, 24 nations and the European Economic Community (EEC) signed the Montreal Protocol on Substances that Deplete the Ozone Layer. Most of the major CFC and halon producing and consuming nations have ratified the agreement.

THE CHEMICALS

Listed below are the eight chemicals controlled by the Montreal Protocol:

- Fully-Halogenated Chlorofluorocarbons (Grp 1)

CFC-11
CFC-12
CFC-113
CFC-114
CFC-115

- Halons (Grp. 2)

Halon-1211
Halon-1301
Halon-2402

Within each group of substances (CFCs and halons), each individual chemical (e.g., Halon-1211) is assigned an ozone depletion weight, a measure of its relative ability to destroy ozone molecules in the stratosphere.

These weights are:

Chemical Compound	Depletion Weight
CFC-11	1.0
CFC-12	1.0
CFC-113	0.8
CFC-114	1.0
CFC-115	0.6
Halon-1211	3.0
Halon-1301	10.0
Halon-2402	To be determined

FOCUS ON CFC-12

Mobile air conditioners, which cool the passenger compartments of automobiles, trucks, and buses, are the largest single use of CFCs in the United States. CFC-12 is used for this purpose. A/C systems used an estimated 54,000 metric tons of CFC-12 in 1985. Out of 15.3 million motor vehicles manufactured or imported in that year, between 80 and 90 percent had factory-installed air conditioners. At present, CFC-12 is the only refrigerant used in cars and trucks.

CFC use in A/C systems represents a large percentage of total ozone-depleting potential of CFCs in the United States.

Although CFCs can escape into the air from A/C systems at various times, most escape when vehicles are serviced. There are about 200,000 establishments in the United States, from gas stations to automobile dealerships, that service A/C systems. Together, the initial charge of new units plus later charges to replace losses represent over 90 percent of CFCs released from A/C systems. Most of the remaining releases occur during vehicle disposal.

CURRENT ALTERNATIVES

Manufacturers have identified HFC-134a as a substitute for CFC-12 and are improving the design of the A/C system to reduce CFC releases. The major alternatives are as follows:

- Improved system design and components. Design improvements are already being implemented to reduce CFC leakage from A/C systems. These include the use of improved containment of refrigerants, shorter hoses, and improved compressor seals and fittings. In addition, controls are used to shut off the system when the system has a low refrigerant charge. The vehicle can then be taken in for service and leak detection before more refrigerant is lost.
- Recovery and recycling of CFC refrigerant. Shops servicing A/C systems can use recovery units to withdraw refrigerant, purify it, and return it to the system. "Recovery at service," as this process is known, requires a capital investment, but shops can also achieve cost savings by using recycled CFCs.
- Blends. Although not in use currently, may cause system problems and cannot be identified if mixed with CFC-12. (The same holds true for recycling equipment.)

FUTURE ALTERNATIVES

Chemical substitutes are expected to replace CFC-12 eventually, even though they will require design modifications in A/C systems. The most promising new chemical is HFC-134a, now undergoing extensive toxicity and use testing. If test results are favorable, new cars could begin using alternative chemicals in the mid-1990's. (See page 13 for more information about HFC-134a.)

Various hydrocarbon compounds are also possible alternatives. However, because they are flammable, hydrocarbon systems would require safety features in order to achieve widespread use.

MACS NOTE

CROSS-CONTAMINATION OF SYSTEM REFRIGERANT

WITH MULTIPLE REFRIGERANTS IN MOBILE AIR CONDITIONING SYSTEMS, IDENTIFICATION OF THE REFRIGERANT IN THE SYSTEM WILL MANDATE SERVICE PROCEDURES AND EQUIPMENT TO BE USED TO AVOID SYSTEM AND EQUIPMENT DAMAGE.

CAUTION: THIS INCLUDES MANIFOLD GAUGE SETS, HOSES, CHARGING AND RECYCLING EQUIPMENT.

Refrigerant Recycling: The Concept

FIELD STUDY

Due to the gravity of the ozone depletion issue, industry efforts were immediately directed toward determining if CFCs used in the mobile air conditioning service industry could be recycled.

During the summer of 1988, the EPA, with the support of the Mobile Air Conditioning Society (MACS) initiated a sampling program of used refrigerant from 227 vehicles from four regions of the country. These vehicles included properly operating systems, failed compressors, low mileage vehicles and vehicles with over 100,000 miles. The chemical analysis of the removed refrigerant indicated a low amount of contamination. From the field study results, the task force established specifications for recycled refrigerant and requested the world auto manufacturers to approve the level of purity in December, 1988. Many automobile and truck manufacturers have accepted recycled CFC-12 for service and warranty repairs.

SYSTEM CONTAMINANTS

Data gleaned from the field study of CFC-12 from mobile air conditioning systems identified moisture, refrigerant oil and non-condensable gases (air) as contaminants in used refrigerant that could affect system performance and life.

A consensus was achieved establishing the standard of purity for recycled R-12 refrigerant. Recycled refrigerant may not exceed the level of contaminants specified by SAE J1991:

- Moisture: 15 PPM by weight,
- Refrigerant oil: 4000 PPM by weight,
- Non-condensable gases (air): 330 PPM by weight.

STANDARDS DEVELOPED

Based on the field study, the Society of Automotive Engineers' R-12 task force established three documents to cover the mobile air conditioning industry use of CFCs. The documents include:

- SAE J1989: Service Procedures (See page 5.)
- SAE J1990: Specifications for Recycling Equipment
- SAE J1991: Purity Requirement of Recycled Refrigerant.

WHY RECYCLE?

With over 65.8% of the CFC-12 used in the mobile air conditioning industry for service, current service practices that involve venting of the chemical can no longer be considered acceptable. This includes the addition of CFCs to systems that have leaks and are not repaired prior to recharge and charging equipment that requires venting to fill the measuring device. Proper procedures for containment of CFCs during service and proper disposal of residual from containers prior to disposal are covered in SAE J1989.

From limited information presently available, service facilities that have used recycling equipment during the summer of 1989 have realized approximately a 50% reduction in CFC-12 usage.

If the sale of CFC's were limited to facilities that have trained personnel and certified recycling equipment, a major reduction of CFC usage could be attained.

It is important that CFC-12 be available beyond the year 2000 to assure that vehicles produced with CFC-12 can be serviced for the life expectancy of the vehicle. Without CFC-12 for service in the time period, conversion or obsolescence of vehicles will result in a major economic impact for the owners.

Although the mobile air conditioning industry is scheduled to phase in HFC-134a in the mid-1990's, CFC-12 systems will still be produced before then. With a 5 to 10 year vehicle life expectancy, CFC-12 will be required for service well beyond the year 2000. If CFC-12 is not available for service, the consumer will have to choose whether to convert to a new refrigerant, to purchase a new vehicle with HFC-134a, or to do without air conditioning.

Controlled sale of CFCs, proper repair of leaking systems and recycling of existing CFCs are required to assure consumers the use of their air conditioning systems beyond the year 2000.

With effective controls of CFC supplies and mandatory recycling at all servicing levels, the auto industry can affect a major reduction of new CFC-12 production requirements in the mid-1990's.

SAE J1989 • Recommended Service Procedure

Recommended Service Procedure for the Containment of R-12
SAE Recommended Practice
Issued October 1989

1. SCOPE:
During service of mobile air conditioning systems, containment of the refrigerant is important. This procedure provides service guidelines for technicians when repairing vehicles and operating equipment defined in SAE J1990.

2. REFERENCES:
SAE J1990, Extraction and Recycle Equipment for Mobile Automotive Air Conditioning Systems

3. REFRIGERANT RECOVERY PROCEDURE:

3.1 Connect the recovery unit service hoses, which shall have shutoff valves within 12 inches (30 cm) of the service ends, to the vehicle air conditioning system service ports.

3.2 Operate the recovery equipment as covered by the equipment manufacturer's recommended procedure.

3.2.1 Start the recovery process and remove the refrigerant from the vehicle A/C system. Operate the recovery unit until the vehicle system has been reduced from a pressure to a vacuum. With the recovery unit shut off for at least 5 minutes, determine that there is no refrigerant remaining in the vehicle A/C system. If the vehicle system has pressure, additional recovery operation is required to remove the remaining refrigerant. Repeat the operation until the vehicle A/C system vacuum level remains stable for 2 minutes.

3.3 Close the valves in the service lines and then remove the service lines from the vehicle system. Proceed with the repair/service. If the recovery equipment has automatic closing valves, be sure they are properly operating.

4. SERVICE WITH MANIFOLD GAUGE SET:

4.1 Service hoses must have shutoff valves in the high, low and center service hoses within 12 inches (30 cm) of the service ends. Valves must be closed prior to hose removal from the air conditioning system. This will reduce the volume of refrigerant contained in the service hose that would otherwise be vented to atmosphere.

4.2 During all service operations, the valves should be closed until connected to the vehicle air conditioning system or the charging source to avoid introduction of air and to contain the refrigerant rather than vent open to atmosphere.

4.3. When the manifold gauge set is disconnected from the air conditioning system or when the center hose is moved to another device which cannot accept refrigerant pressure, the gauge set hoses should first be attached to the reclaim equipment to recover the refrigerant from the hoses.

5. RECYCLED REFRIGERANT CHECKING PROCEDURE FOR STORED PORTABLE AUXILIARY CONTAINER:

5.1 To determine if the recycled refrigerant container has excess non-condensable gases (air), the container must be stored at a temperature of 65°F (18.3°C) or above for a period of time, 12 hours, protected from direct sun.

5.2 Install a calibrated pressure gauge, with 1 psig divisions (0.07 kg), to the container and determine the container pressure.

5.3 With a calibrated thermometer, measure the air temperature within 4 inches (10 cm) of the container surface.

5.4 Compare the observed container pressure and air temperature to determine if the container exceeds the pressure limits found on Table 1, e.g. air temperature 70°F (21°C) pressure must not exceed 80 psig (5.62 kg/cm^2).

5.5 If the container pressure is less than the Table 1 values and has been recycled, limits of non-condensable gases (air) have not been exceeded and the refrigerant may be used.

5.6 If the pressure is greater than the range and the container contains recycled material, slowly vent from the top of the container a small amount of vapor into the recycle equipment, until the pressure is less than the pressure shown on Table 1.

5.7 If the container still exceeds the pressure shown on Table 1, the entire contents of the container shall be recycled.

6.. CONTAINERS FOR STORAGE OF RECYCLED REFRIGERANT:

6.1 Recycled refrigerant should not be salvaged or stored in disposable refrigerant containers. This is the type of container in which virgin refrigerant is sold. Use only DOT CFR Title 49 or UL approved storage containers for recycled refrigerant.

6.2 Any container of recycled refrigerant that has been stored or transferred must be checked prior to use as defined in Section 5.

7. TRANSFER OF RECYCLED REFRIGERANT

7.1 When external portable containers are used for transfer, the container must be evacuated to at least 27 inches of vacuum (75 mm Hg absolute pressure) prior to transfer of the recycled refrigerant. External portable containers must meet DOT and UL standards.

7.2 To prevent on-site overfilling when transferring to external containers, the safe filling level must be controlled by weight and must not exceed 60% of container gross weight rating.

8. DISPOSAL OF EMPTY/NEAR CONTAINERS:

TABLE 1

TEMP°F	PSIG	TEMP°F	PSIG	TEMP°F	PSIG	TEMP°F	PSIG	TEMP°F	PSIG
65	74	75	87	85	102	95	118	105	136
66	75	76	88	86	103	96	120	106	138
67	76	77	90	87	105	97	122	107	140
68	78	78	92	88	107	98	124	108	142
69	79	79	94	89	108	99	125	109	144
70	80	80	96	90	110	100	127	110	146
71	82	81	98	91	111	101	129	111	148
72	83	82	99	92	113	102	130	112	150
73	84	83	100	93	115	103	132	113	152
74	86	84	101	94	116	104	134	114	154

TABLE 1 (Metric)

TEMP°C	PRES	TEMP°C	PRES	TEMP°C	PRES	TEMP°C	PRESG	TEMP°C	PRES
18.3	5.20	23.9	6.11	29.4	7.17	35.0	8.29	40.5	9.56
18.8	5.27	24.4	6.18	30.0	7.24	35.5	8.43	41.1	9.70
19.4	5.34	25.0	6.32	30.5	7.38	36.1	8.57	41.6	9.84
20.0	5.48	25.5	6.46	31.1	7.52	36.6	8.71	42.2	9.98
20.5	5.55	26.1	6.60	31.6	7.59	37.2	8.78	42.7	10.12
21.1	5.62	26.6	6.74	32.2	7.73	37.7	8.92	43.3	10.26
21.6	5.76	27.2	6.88	32.7	7.80	38.3	9.06	43.9	10.40
22.2	5.83	27.7	6.95	33.3	7.94	38.8	9.13	44.4	10.54
22.7	5.90	28.3	7.03	33.9	8.08	39.4	9.27	45.0	10.68
23.3	6.04	28.9	7.10	34.4	8.15	40.0	9.42	45.5	10.82

PRES kg/sq cm

8.1 Since all the refrigerant may not be removed from disposable refrigerant containers during normal system charging procedures, empty/near empty container contents should be reclaimed prior to disposal of the container.

Attach the container to the recovery unit and remove the remaining refrigerant. When the container has been reduced from a pressure to a vacuum, the container valve can be closed. The container should be marked empty and is ready for disposal.

SAE J1989 • Issued October 1989
Recommended Service Procedure for the Containment of R-12
© Society of Automotive Engineers, Inc., 1989

Safety Precautions • Warnings

1. Failure to follow instructions provided by recycling equipment manufacturers could result in personal injury or equipment damage.

2. Always wear safety goggles when servicing an air conditioning system or handling refrigerant. REFER TO MATERIAL SAFETY DATA SHEET PROVIDED BY YOUR REFRIGERANT SUPPLIER FOR INFORMATION REGARDING THE PROPER HANDLING OF REFRIGERANT.

3. NEVER perform service on the recycling equipment (other than routine maintenance) without first consulting authorized service personnel. The removal of internal fittings and filters can cause refrigerant under pressure to be expelled. Use care and always wear safety glasses.

4. NEVER perform maintenance or service on the recycling equipment with the unit plugged in unless directed otherwise.

5. NEVER transfer refrigerants to a cylinder or tank unless it is Department of Transportation approved for refilling. DOT approval is indicated by "DOT 4BW" or "DOT 4BA."

6. Recycling equipment incorporates parts, such as snap switches which tend to produce arcs or sparks and therefore, when located in a garage it should be used in locations with mechanical ventilation that provides at least four air changes per hour or the equipment should be located at least 18 inches (457 mm) above the floor, as specified by the UL 1963 standard.

7. Avoid the use of an extension cord with equipment to assure safe and proper operation of the equipment. Under extreme situations that extension cords are required, use minimum length three-wire (No. 14 AWG minimum) with ground circuit. To prevent shock hazard and reduce the risk of fire, make sure extension cord is in good condition (not worn or frayed) with ground circuit intact.

Equipment Certification

The standard for equipment that is certified to be used for refrigerant recycling is established by SAE J1990, and Underwriters Laboratories Inc. certifies that this equipment will meet the purity requirements of SAE J1991. This level of purity is recognized by the auto industry for warranty service applications.

The standard of purity for recycled R-12 refrigerant for use in mobile A/C systems, that has been directly removed from auto A/C systems, shall not exceed the following levels of contaminants:

- Moisture: 15 parts per million (PPM) by weight
- Refrigerant Oil: 4000 PPM by weight
- Non-condensable Gases (Air): 330 PPM by weight

Underwriters Laboratories Inc. is certifying refrigerant recycling equipment:

- To UL requirements for safety and
- To SAE J1990 performance requirements

Equipment that has passed UL testing procedures will be marked with the four element LISTING MARK (UL in a circle, the word LISTED, CFC-12 Recycling Equipment, and the control number), and "Design Certified by Underwriters Laboratories Inc. for compliance with SAE J1991 (1989)."

Containers: Handle With Care

CAUTION: NEVER USE A STANDARD DISPOSABLE 30 LB. TANK (THE TYPE OF CONTAINER IN WHICH VIRGIN REFRIGERANT IS SOLD) TO RECLAIM REFRIGERANT-12. USE ONLY DOT CFR TITLE 49 OR UL APPROVED STORAGE CONTAINERS FOR RECYCLED REFRIGERANT.

THERMAL EXPANSION

A. Safety codes recommend that closed tanks not be filled over 80 % of the volume with liquid. The remaining 20% is called head pressure room.

B. Refrigerant expands when it gets warm.

C. When the refrigerant expands some of it boils thus increasing the pressure.

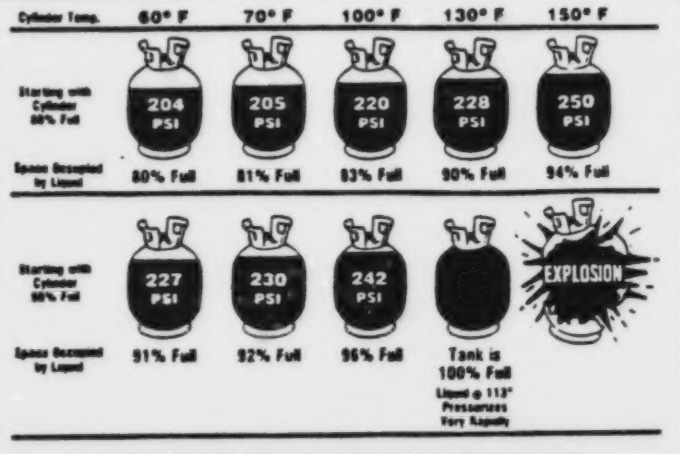
D. Remaining liquid expands rapidly and may fill the container 100% full with liquid.

E. The fuller the tank the more liquid expansion takes place.

F. Pressure within the tank increases at a slower rate if there is room for the gases. The pressure increases according to the liquid saturation.

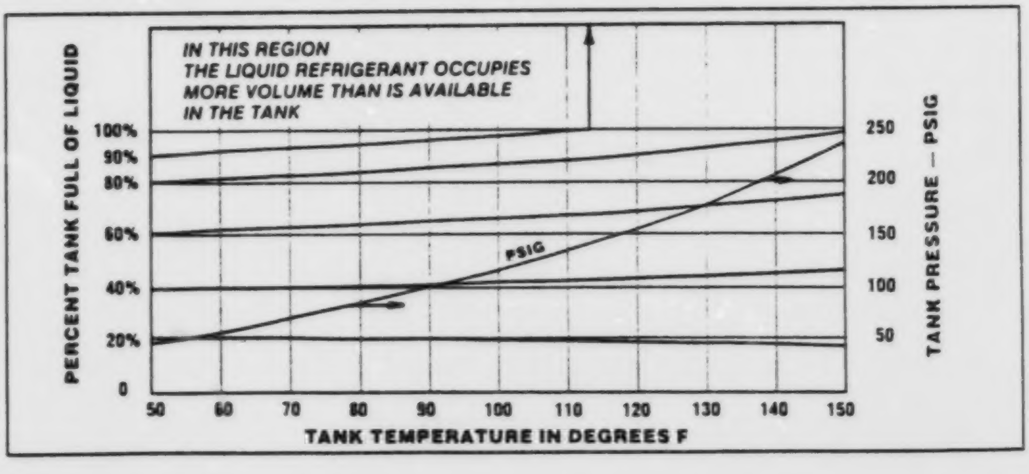
G. As you can see from the chart below, the tank filled with 80% liquid is relatively safe.* However, the tank filled with 90% liquid is in essence a time bomb. A 90% fill causes pressure within the tank to rise at a very rapid rate. At temperatures above 100° F, the tank may explode.

© Murray Corporation, 1989

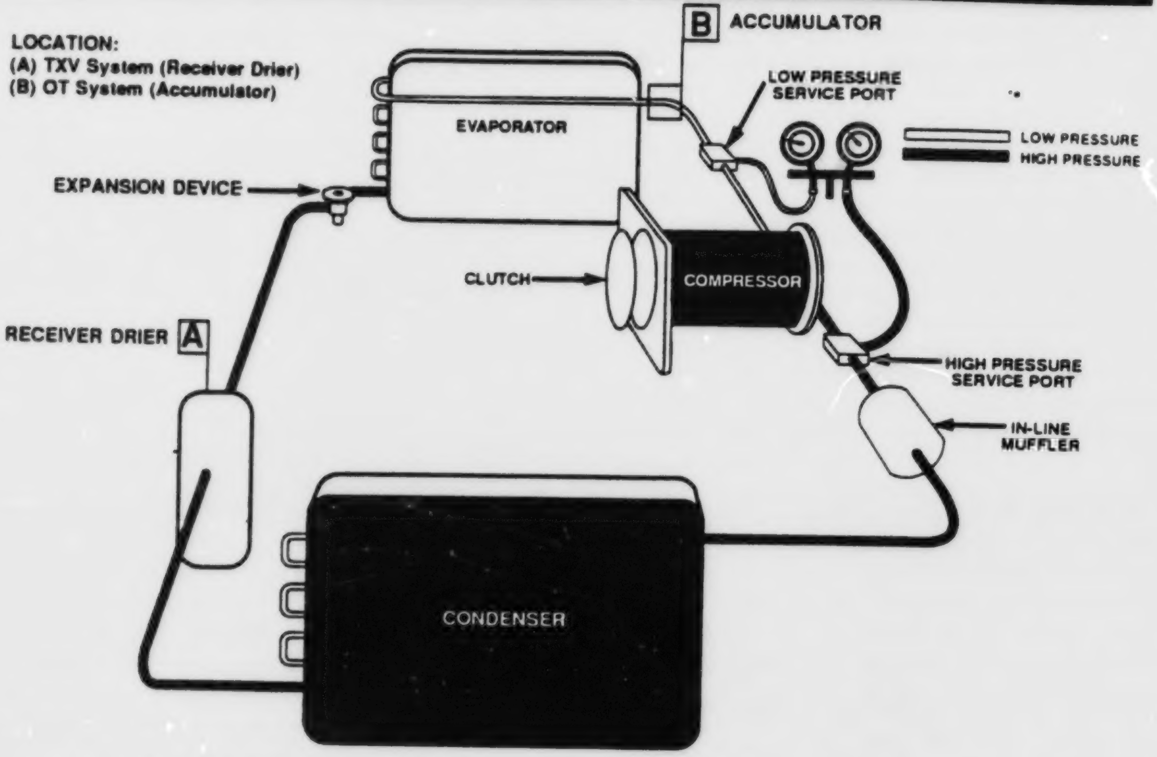

Cylinder Temp.
60° F
70° F
100° F
130° F
150° F
Starting with Cylinder 80% Full
204 PSI
205 PSI
220 PSI
228 PSI
250 PSI
Space Occupied by Liquid
80% Full
81% Full
83% Full
90% Full
94% Full
Starting with Cylinder 90% Full
227 PSI
230 PSI
242 PSI
EXPLOSION
Space Occupied by Liquid
91% Full
92% Full
96% Full
Tank is 100% Full
Liquid @ 113° Pressurizes Very Rapidly

DO NOT OVERFILL REFRIGERANT TANKS

*** Note: SAE J1989, Section 7.2, states:**
"To prevent on-site overfilling when transferring to external containers, the safe filling level must be controlled by weight and must not exceed 60 % of container gross weight rating."



Typical Hookup for A/C Service


B ACCUMULATOR
LOCATION:
(A) TXV System (Receiver Drier)
(B) OT System (Accumulator)
LOW PRESSURE SERVICE PORT
EVAPORATOR
LOW PRESSURE
HIGH PRESSURE
EXPANSION DEVICE
CLUTCH
COMPRESSOR
RECEIVER DRIER A
HIGH PRESSURE SERVICE PORT
IN-LINE MUFFLER
CONDENSER

NOTE: Low and high side service port hookups may be found anywhere within the respective system loops.

Proper hookup of refrigerant lines to the system must include shut-off valves on the end of every line. Shut-off valves should be no more than 12 inches from the port where the lines are connected (SAE J1989).

Use of a shut-off valve at the hookup for refrigerant canisters will also help ensure minimum refrigerant loss.

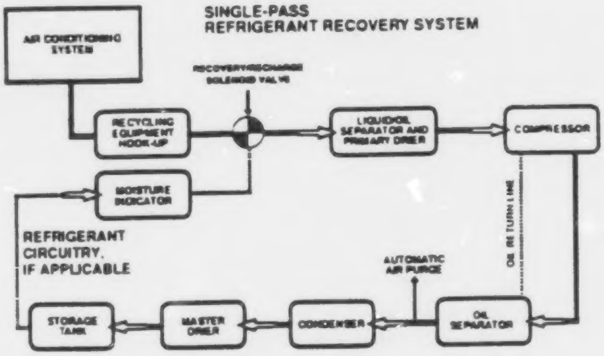
Shut off valves may be either manual, as shown above, or automatic. While SAE J1989 says shut-off valves must be used within 12 inches of a connection, some equipment manufacturers use quick-couplers, which automatically shut off the flow of refrigerant when connections are broken. When quick-couplers are used, follow the equipment manufacturer's recommendations.

Recovery & Recycling

Shown here are two types of refrigerant recovery/recycling systems: single-pass and multi-pass. Both systems remove the refrigerant from the vehicle and provide a process for cleaning and storing refrigerant.

SINGLE-PASS SYSTEM

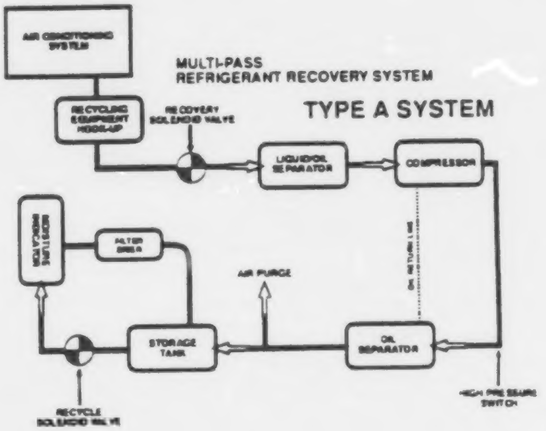
In single pass systems, refrigerant is drawn from the vehicle, passes through an oil separator which removes any oil, and a filter/drier assembly which removes moisture and particle contamination. After a single cycle, the contaminant-free R-12 is sent to a storage tank.


SINGLE-PASS
REFRIGERANT RECOVERY SYSTEM
AIR CONDITIONING SYSTEM
RECOVERY/RECHARGE SOLENOID VALVE
RECYCLING EQUIPMENT HOOK-UP
LIQUID/OIL SEPARATOR AND PRIMARY DRIER
COMPRESSOR
MOISTURE INDICATOR
REFRIGERANT CIRCUITRY, IF APPLICABLE
OIL RETURN LINE
AUTOMATIC AIR PURGE
STORAGE TANK
MASTER DRIER
CONDENSER
OIL SEPARATOR

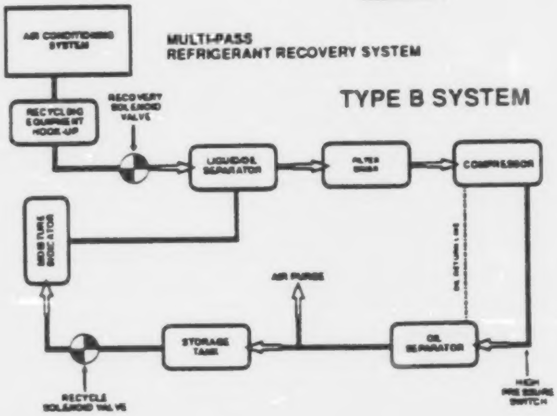
MULTI-PASS SYSTEM

In multi-pass systems, refrigerant is drawn from the vehicle, passes through an oil separator which removes any oil, and a filter/drier assembly which removes moisture and particle contamination and then is stored in a tank. (NOTE: Arrangement of system components differs among equipment manufacturers, as shown by diagrams A and B at right.)

When recycling is desired, the recycle solenoid valve is opened allowing a continuous loop filtering process in which the refrigerant passes through a desiccant (drier) cartridge several times, until the moisture is fully removed. The station has an indicator to alert the service technician — or will automatically vent the recovery tank — to remove air. A moisture indicator will show when the refrigerant is ready for use.


MULTI-PASS
REFRIGERANT RECOVERY SYSTEM

TYPE A SYSTEM
AIR CONDITIONING SYSTEM
RECYCLING EQUIPMENT HOOK-UP
RECOVERY SOLENOID VALVE
LIQUID/OIL SEPARATOR
COMPRESSOR
MOISTURE INDICATOR
FILTER DRIER
AIR PURGE
OIL RETURN LINE
STORAGE TANK
OIL SEPARATOR
RECYCLE SOLENOID VALVE
HIGH PRESSURE SWITCH


MULTI-PASS
REFRIGERANT RECOVERY SYSTEM

TYPE B SYSTEM
AIR CONDITIONING SYSTEM
RECYCLING EQUIPMENT HOOK-UP
RECOVERY SOLENOID VALVE
LIQUID/OIL SEPARATOR
FILTER DRIER
COMPRESSOR
MOISTURE INDICATOR
OIL RETURN LINE
AIR PURGE
STORAGE TANK
OIL SEPARATOR
RECYCLE SOLENOID VALVE
HIGH PRESSURE SWITCH

FOLLOW MANUFACTURER'S INSTRUCTIONS

When using a refrigerant recovery or recycling station, observe the following general procedures as well as the operating instructions provided by the equipment manufacturer.

Recommended Service Procedures

ENSURE SYSTEM INTEGRITY

As a first step in service, always perform a visual inspection to spot obvious problems before charging a system for testing.

Be sure to check service valve fittings and O-ring integrity in dust caps. Missing caps and seals at system valve ports are major leak sources. Caps and seals must be properly inspected and installed after service to minimize refrigerant loss.

LEAK TESTING

Use the minimum necessary amount of refrigerant for leak testing and checking system function. One pound of refrigerant or less should be adequate for leak testing*.

*CAUTION: DO NOT OPERATE THE COMPRESSOR WITHOUT THE FULL CHARGE OF REFRIGERANT SPECIFIED BY THE OE MANUFACTURER.

Reclaim the test charge of refrigerant, then make the necessary repairs.

After repairs have been completed, the system should be thoroughly leak tested.

CHECK EQUIPMENT

Recycling equipment should also be checked on a monthly basis to ensure that no leakage occurs.

RECLAIM ALL REFRIGERANT

All cylinders containing CFC-12 should be connected to a recycling machine and brought to a vacuum before they are discarded.

OE Manufacturers Charging Procedures

Listed below are refrigerant system recovery and charging procedures specified by three of the auto manufacturers.

Refrigerant charges are critical to air conditioning system performance. Always follow manufacturers' specifications.

Chrysler

To assist in protecting the ozone layer, Chrysler Motors recommends that an R-12 refrigerant recycling device that meets SAE standard J1991 be used. Refer to the operating instructions provided with the recycling equipment for proper operation.

CHARGING REFRIGERANT SYSTEM

After the refrigerant system has been tested for leaks and evacuated, a 1078 g (38oz) R-12 refrigerant charge can be injected into the refrigerant system. To charge the refrigerant system:

1. Connect a suitable charging station or manifold gauge set to the service ports.

2. Measure 1078 g (38oz) R-12 of refrigerant charge and heat it to 52°C (125°F). Refer to the instructions provided with the equipment being used.

3. Open the suction and discharge valves. Open the charge valve to allow the heated refrigerant to flow into the system. When the transfer of refrigerant has stopped, close the suction and discharge valve.

4. If all of the refrigerant charge did not transfer from the dispensing device, start the engine and hold idle at 1600 rpm. Set the A/C control to A/C, low blower, and open windows. If the A/C compressor does not engage, test the compressor clutch control circuit and correct any failure.

5. Open the suction valve to allow the remaining refrigerant to transfer to the system.

6. Close all valves and test the A/C system overall performance.

7. Disconnect the charging station or manifold gauge set and install the service port caps.

Ford/Lincoln/Mercury

In order to minimize the discharge of ozone depleting chlorofluorocarbons into the atmosphere, the Ford Motor Co. supports the efficient usage, recovery, and recycling of R-12 used in car and truck air conditioners. Ford Motor Co. recommends the use of an U.L. approved recovery/recycling device such as Rotunda model no. 158-00001 or 158-00002 (or other device which meets SAE standard J1991) during any A/C system repair and recharge procedure which requires the A/C system to be discharged.

1. With the manifold gauge set valves closed to the center hose, disconnect the vacuum pump from the manifold gauge set.

2. Connect the center hose of the manifold gauge set to a refrigerant charging cylinder. If a charging station is used, follow the instructions of the manufacturer.

3. Loosen the center hose at the manifold gauge set and open the refrigerant charging cylinder valve. Allow refrigerant to escape to purge air and moisture from the center hose. Then, tighten the center hose connection at the manifold gauge set.

4. Disconnect the wire harness snap-lock connector from the clutch cycling pressure switch and install a jumper wire across the two terminals of the connector.

5. Open the manifold gauge set low side valve to allow refrigerant to enter system. Keep refrigerant cylinder in an upright position if the vehicle low pressure service gauge port is not on the suction accumulator/drier or suction accumulator fitting.

6. When no more refrigerant is being drawn into the system, start the engine and move the air function control lever to the A/C position, and the blower switch to HI to draw the remaining refrigerant in to the system. Continue to add refrigerant to the system until the specified weight of Refrigerant-12 is in the system. Then, close the manifold gauge set low pressure valve and the refrigerant supply valve.

7. Remove the jumper wire from the clutch cycling pressure switch snap-lock connector. Connect the connector to the pressure switch.

8. Operate the system until the pressure stabilizes to verify normal operation and system pressures.

9. In high ambient temperature, it may be necessary to operate a high volume fan positioned to blow air through the radiator and condenser to aid in cooling the engine and prevent excessive refrigerant system pressures.

10. When charging is complete and system operating pressures are normal, disconnect the manifold gauge set from the vehicle. Install protective caps on the service gauge port valves.

(NOTE: The vehicle can be liquid charged using a charging station or charging cylinder. However, engine must be OFF during this procedure.)

General Motors

General Motors Corporation and its dealers will comply with the Montreal Protocol by eliminating the practice of "venting" R-12 into the atmosphere. Starting with the 1991 model year all service facilities and dealers will use refrigerant recovery and recycling equipment when service procedures warrant discharging of the air conditioning system.

MINIMUM EQUIPMENT REQUIREMENTS

General Motors dealers are required to use equipment certified for both operational safety and standard of purity J1991 by Underwriters Laboratories.

The Kent-Moore ACR 3, J38100B, is recommended by the General Motors tool committee.

REFRIGERANT RECOVERY

The refrigerant system must be discharged using an Air Conditioning Refrigerant Recovery and Recycling System J 38100-D. After repairing the malfunction, the refrigerant system can then be evacuated and charged using air conditioning service charging station J 23500-A or equivalent, or the manifold and gauge set J 23575-01 and refrigerant.

Evacuation lines from the recovery system and the charging lines from the charging station or manifold and gauge set require the use of adapters to connect the A/C system low-side service fitting. A straight adapter J 5420 and a 90 degree angle adapter J 9459 are available.

NOTICE: Failure to check for residual oil from the previous recovery can result in adding extra oil to the vehicle currently being serviced. This will result in reduced performance and possible compressor damage.

1. Start vehicle and run with A/C on for two minutes. Then attach a manifold gauge set to the A/C system and attach the recovery station inlet hose to the center fitting of the manifold gauge set.

2. Open both valves of the manifold gauge set. Make certain the refrigerant tank "VAPOR" valve and the "LIQUID" valve are open.

3. Plug the station into a suitable AC power outlet and turn on the "MAIN POWER" switch.

4. Depress the "COMPRESSOR START" switch. The amber "COMPRESSOR ON" light will come on and the compressor will start. The compressor will shut off automatically when recovery is complete. Wait two minutes and check for pressure rise. If pressure rise occurs, depress "COMPRESSOR START" switch and allow equipment to repeat the recovery.

5. To drain the accumulator of A/C system oil, open the "ACCUMULATOR PRESSURIZING" valve long enough to allow some compressor discharge pressure back into the accumulator. Open the oil drain valve slowly and drain the accumulator. When the oil stops draining, close the oil drain valve. Do not allow the accumulator to completely depressurize.

6. Although refrigerant can be filtered and recycled at

any time, it is recommended to recycle when the tank is full for greatest efficiency. Two tanks are provided so you can fill one, recycle it, and use it for charging systems while filling the second tank.

When the recovery tank is full, the trip switch at the bottom of the weight platform will de-energize the compressor and the "TANK FULL" light will come on. Close both tank valves, remove the tank from the platform, and replace with another refillable tank or recycle the first tank. If the first tank isn't immediately recycled, take precautions to prevent its use in A/C systems before it is recycled

MACS NOTE

CAUTION: THE FITTING ON THE FUEL INJECTION PLUMBING WHICH CONTAINS COMBUSTIBLE FLUIDS IS THE SAME SIZE AS THE A/C SERVICE FITTINGS. BE CAREFUL NOT TO ATTACH THE A/C SERVICE LINES TO THE VEHICLE FUEL SYSTEM.

A Look at the Future • HFC-134a

The need for the auto industry to replace ozone depleting CFC-12 has resulted in new engineering challenges. The best candidate for a replacement refrigerant is HFC-134a which is a chemical that only recently received the first level of approval for toxicity. The second level of toxic testing will not be completed until 1992, which is the expected time period for the first commercial production of the new refrigerant.

Considering that HFC-134a was the best choice for the mobile air conditioning industry, development programs were started in late 1987 and early 1988 for adaptation of the systems for future production. The system changes cover many areas and the industry phase-in will require some time. Availability of the new chemical from the producers for OEM initial factory fill and sufficient quantity for the service industry in the field is important.

The major problem has been development of a compatible lubricant which will provide the same compressor durability as expected in CFC-12 systems. Current lubricant development has resulted in many different formulations, which may result in field service problems if the lubricants are mixed during system service.

Current production mobile air conditioning systems comply to SAE J639 which requires a label installed on the vehicle that indicates the type and amount of refrigerant charge. Modifications of J639 will also include new refrigerant service fittings to prevent mixing of refrigerants during service and also identify the type of lubricant required in the system.

Mobile air conditioning systems that use a sight glass for establishing system charge level may not be reliable since layering conditions exist with the new lubricant and the HFC-134a resulting in improper visual servicing of charge level.

The moisture level of HFC -134a systems may become a problem compared to CFC-12 systems. The absorbing capability of both HFC-134a and current PAG lubricants indicate that the molecular sieve desiccant must be a new specification and 25% larger by weight to be comparable with CFC-12 systems.

The current CFC-12 desiccants are not compatible with HFC-134a and can result in a field problem if they are mixed during service.

New materials for containment of HFC-134a are required for flexible hoses, O-rings and seals.

Some engineering test programs have experienced material transfer problems with operating systems. It is not known what the exact conditions are that create the problem, however there is concern that the additives in the lubricant may effect the transfer of some material which is in direct contact with the refrigerant and lubricant.

The higher operating pressures of HFC-134a as compared to CFC-12 is a problem at high ambient temperature during city traffic and idle conditions. New condenser surfaces with increased heat transfer capability and increased air flow over the condenser are required to resolve the loss of system performance.

Field service of HFC-134a will cause new concerns for the industry since the refrigerant and lubricant are not compatible with CFC-12. This will require separate equipment at the facility to prevent mixing of the refrigerant during service operations.

The current CFC leak detection devices can not identify leakage of HFC-134a and new detection devices will be required.

With the expected cost of HFC-134a and the concern for cradle to grave control of new chemicals, the Society of Automotive Engineers will establish recycle requirements for the mobile air conditioning industry.

When the auto industry first introduced mobile air conditioning to the public, the use of CFCs and system requirements had been established by the air conditioning industry. With the introduction of a new chemical and lubricant, the necessary system design changes and product development for mobile air conditioning systems and manufacturing facilities is a complex, time-consuming process.

The chemical companies in 1991 will complete new plants and processes to produce HFC-134a for production vehicles and the service industry. There may be a short supply during the initial phase for the auto industry.

Considering that HFC-134a is not in volume production and has not completed toxicity testing, implementation for the auto industry by the mid-1990's model year will be a major industry achievement.

Reduced consumption of CFC-12 in the auto industry by restricted supply, recycling and trained service personnel will help reduce the future production requirements for CFC-12.

SAE J1991 OCT89

Standard of Purity for Use in Mobile Air-Conditioning Systems

SAE Standard
Issued October 1989

Submitted for Recognition as
an American National Standard

HIGHWAY VEHICLE STANDARD

Submitted for recognition as an American National Standard

SAE J1991

Issued October 1989

STANDARD OF PURITY FOR USE IN MOBILE AIR-CONDITIONING SYSTEMS

FOREWORD: Due to the CFC's damaging effect on the ozone layer, recycle of CFC-12 (R-12) used in mobile air-conditioning systems is required to reduce system venting during normal service operations. Establishing recycle specifications for R-12 will assure that system operation with recycled R-12 will provide the same level of performance as new refrigerant.

Extensive field testing with the EPA and the auto industry indicate that reuse of R-12 removed from mobile air-conditioning systems can be considered, if the refrigerant is cleaned to a specific standard. The purpose of this standard is to establish the specific minimum levels of R-12 purity required for recycled R-12 removed from mobile automotive air-conditioning systems.

1. SCOPE:

This information applies to refrigerant used to service automobiles, light trucks, and other vehicles with similar CFC-12 systems. Systems used on mobile vehicles for refrigerated cargo that have hermetically sealed, rigid pipe are not covered in this document.

2. REFERENCES

SAE J1989, Recommended Service Procedure for the Containment of R-12

SAE J1990, Extraction and Recycle Equipment for Mobile Automotive Air-Conditioning Systems

ARI Standard 700-88

3. PURITY SPECIFICATION:

The refrigerant in this document shall have been directly removed from, and intended to be returned to, a mobile air-conditioning system. The contaminants in this recycled refrigerant 12 shall be limited to moisture, refrigerant oil, and noncondensable gases, which shall not exceed the following level:

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Printed in U.S

3.1 Moisture: 15 ppm by weight.

3.2 Refrigerant Oil: 4000 ppm by weight.

3.3 Noncondensable Gases (Air): 330 ppm by weight.

4. REFRIGERATION RECYCLE EQUIPMENT USED IN DIRECT MOBILE AIR-CONDITIONING SERVICE OPERATIONS REQUIREMENT:

4.1 The equipment shall meet SAE J1990, which covers additional moisture, aci
and filter requirements.

4.2 The equipment shall have a label indicating that it is certified to meet
this document.

5. PURITY SPECIFICATION OF RECYCLED R-12 REFRIGERANT SUPPLIED IN CONTAINERS F OTHER RECYCLE SOURCES:

Purity specification of recycled R-12 refrigerant supplied in containers f
other recycle sources, for service of mobile air-conditioning systems, sha
meet ARI Standard 700-88 (Air Conditioning and Refrigeration Institute).

6. OPERATION OF THE RECYCLE EQUIPMENT:

This shall be done in accordance with SAE J1989.

RATIONALE:

Not applicable.

RELATIONSHIP OF SAE STANDARD TO ISO STANDARD:

Not applicable.

REFERENCE SECTION:

SAE J1989, Recommended Service Procedure for the Containment of R-12

SAE J1990, Extraction and Recycle Equipment for Mobile Automotive Air-Conditioning Systems

ARI Standard 700-88

APPLICATION:

This information applies to refrigerant used to service automobiles, light trucks, and other vehicles with similar CFC-12 systems. Systems used on mobile vehicles for refrigerated cargo that have hermetically sealed, rigid pipe are not covered in this document.

COMMITTEE COMPOSITION:

DEVELOPED BY THE SAE DEFROST AND INTERIOR CLIMATE CONTROL STANDARDS COMMITTEE:

W. J. Atkinson, Sun Test Engineering, Paradise Valley, AZ - Chairman
J. J. Amin, Union Lake, MI
H. S. Andersson, Saab Scania, Sweden
P. E. Anglin, ITT Higbie Mfg. Co., Rochester, MI
R. W. Bishop, GMC, Lockport, NY
D. Hawks, General Motors Corporation, Pontiac, MI
J. J. Hernandez, NAVISTAR, Ft. Wayne, IN
H. Kaltner, Volkswagen AG, Germany, Federal Republic
D. F. Last, GMC, Troy, MI
D. E. Linn, Volkswagen of America, Warren, MI
J. H. McCorkel, Freightliner Corp., Charlotte, NC
C. J. McLachlan, Livonia, MI
H. L. Miner, Climate Control Inc., Decatur, IL
R. J. Niemiec, General Motors Corp., Pontiac, MI
N. Novak, Chrysler Corp., Detroit, MI
S. Oulouhojian, Mobile Air Conditioning Society, Upper Darby, PA
J. Phillips, Air International, Australia
R. H. Proctor, Murray Corp., Cockeysville, MD
G. Rolling, Behr America Inc., Ft. Worth, TX
C. D. Sweet, Signet Systems Inc., Harrodsburg, KY
J. P. Telesz, General Motors Corp., Lockport, NY

SEA Proposed Standards for CFC 12

(1) Containment
(2) Extraction and Reclamation Equipment
(3) Reclaimed CFC Clean Liners

From Mobile Air Conditioners

SAE PROPOSED STANDARDS

A) J1989 recommended Service Procedure for Containment of CFC-12.

1.0 Scope:

During service of mobile air conditioning systems containing CFC-12 containment of the CFCs is important. This procedure provides service guidelines for the technicians when repairing vehicles and operating equipment defined in J1990. Service hoses must have shut off valves installed and must be closed prior to hose removal from the air conditioning system. This will reduce the volume of CFCs contained in the service hose which would otherwise be vented.

2.0 Refrigerant Recovery Procedure

2.1 connect the unit service hoses to the air conditioning system gage service ports. Open the valves located in the service lines near the system gage service ports.

2.2 Operate the recovery equipment as covered by the manufactures recommended procedure.

2.3 Close the valves in the service lines and then remove the service lines from the system.

3.0 Service with Manifold Gauge Set

3.1 Service hoses must have shut off valves in the high, low and center service hoses within 12 inches of the open ends which are attached to the service gage ports and the center hose which attaches to the charge station or vacuum pump.

3.2 During all service operation the valves should be closed until installed to the air conditioning system or the charging source to contain the CFCs rather than open vent.

3.3 When the manifold gauge set is required for processing, the air conditioning system with the vacuum equipment, the gauge set should be attached to the reclaim equipment and the CFCs removed from the hoses.

4.0 Reclaimed Refrigerant Checking Procedures

4.1 To determine if the recycled refrigerant tank has excess non-condensable (air) the tank must be stored at a minimum temperature of 75 degrees F for 3 days.

4.2 Install a calibrated pressure gauge, with 1 PSI divisions, to the tank and determine the tank pressure.

4.3 Determine the temperature of the air surrounding the tank not to exceed 4 inches of the tank surface.

4.4 compare the observed tank pressure and air temperature to determine if the tank exceeds the pressure limits found on chart .

4.5 If the tank pressure is higher than the chart value, limit on non-condensable (air) have been exceeded.

4.6 If the tank pressure is within range and has been recycled the refrigerant may be used. If the pressure is out of range and the tank contains recycled material slowly vent from the top of the tank a small amount of vapor. If the tank pressure is reduced to meet the chart value the tank can be used.

B) J1990 Extraction and Reclamation Equipment for Mobile Automotive Air Conditioning Systems.

1.0 Scope:

Due to the CFCs damaging effect on the ozone layer, reclaim of CFC-12 used in mobile air conditioning systems is required to reduce system venting during normal service operations. Establishing reclaim specifications for CFC-12 will assure that system operation with reclaimed CFC-12 will provide the same level of performance as new refrigerant.

Extensive field testing with the EPA and the auto industry indicate that re-use of CFC-12 can be considered, provided that the refrigerant is cleaned to a specific standard. The purpose of this recommended practice, is to establish the specific minimum levels of CFC-12 purity, required for reclaimed CFC-12 for use in mobile automotive air conditioning systems.

3.0 Background

The purpose of this standard is to provide guidelines and standards of purity for CFC-12 recovery, recycling and/or recharging system. This information applies to automobiles, light trucks and other vehicles with similar CFC-12 systems. Systems used on mobile vehicles for refrigerated cargo which have hermetically sealed, rigid-pipe, are not covered in this standard.

4.0 Specification and General Description

The equipment must be able to extract and process CFC-12 from mobile air conditioning systems as defined in J1991. The equipment shall be suitable for use in an automotive service garage environment.

5.0 Refrigeration Reclamation Equipment Requirements

5.1 Moisture and acid

Incorporate a desiccant package that must be replaced when saturated with moisture and whose acid capacity is at least 5% (percent) by weight of total system dry desiccant.

5.2 Filter

Incorporate an in-line filter of 15 microns or less.

5.3 Non-Condensable Gas

If the equipment has a self contained recovery tank, a device to alert the operator that the non-condensable level has been exceeded is required. When external portable tanks, which must meet DOT standards, are used for transfer, the equipment must have a device that will not permit transfer of therecycled refrigerant to the tank unless the tank has been evacuated.

5.4 Transfer of Recycled Refrigerant

Recycled refrigerant for recharging and transfer shall be taken from the liquid phase only.

6.0 Equipment Specification

6.1 The equipment must meet the requirements of this standard.

6.2 Equipment Certification

The equipment must be certified by underwriters laboratories or an equivalent certifying laboratory.

7.0 Safety Requirements

7.1 The unit must comply with federal, state and local requirements on equipment related to the handling of CFC-12 material. Safety precautions or notices related to the safe operation of the equipment shall be prominently displayed on the unit and should also state "caution should be operated by qualified personnel".

8.0 Operating Instructions

8.1 The equipment manufacture must provide operating instruction, necessary maintenance procedures and source information for replacement parts and repair.

8.2 The unit must prominently display the manufacturers' name and address, any items that require maintenance or replacement that effect the proper operation of the unit.

9.0 Functional Description

9.1 The unit must be capable of insuring complete recovery of the CFC-12 from the system being serviced, by reducing the system to a vacuum.

9.2 Unit must be equipped with a high pressure shut off device or mechanical pressure relief located adjacent to the tank used to store the reclaimed refrigerant.

9.3 Portable refillable tanks or containers used in conjunction with this equipment must meet applicable DOT standards and be adaptable with existing refrigerant service and charging equipment.

9.4 The unit must provide, tamper proof, overfill protection to assure that during filling or transfer, the tank or storage container cannot exceed 80% of it's maximum rating as defined by DOT standards.

9.5 All flexible hoses must meet SAE J51 standard.

9.6 Service hoses must have shut off devices located within 12 inches of the connection point to the system being serviced to minimize introduction of non-condensable gases into the recovery equipment and the release of the refrigerant when being disconnected.

9.7 The unit must be able to separate oil based lubricant from recovered refrigerant and accurately measure in 1.0 oz. units.

9.8 The unit must be compatible with leak detector dye that may be present in the system.

10.0 Testing

This test procedure and requirements are used for evaluation of the equipment for it's ability to clean the contaminated CFC-12 refrigerant.

10.1 The equipment shall clean the contaminated CFC-12 refrigerant to the minimum purity level when tested in accordance with the following conditions.

10.2 For test validation the equipment is to be operated according to the manufacturers instructions.

10.3 The equipment is to be operated according to the manufactures instructions. The equipment must be pre-conditioned with 30 lbs. (13.6 kg) of the standard contaminated CFC-12 at an ambient of 70 degrees °F before starting the test cycle.

10.4 Contaminated CFC-12 samples

10.4.1 Standard contaminated CFC-12 refrigerant shall consist of liquid CFC-12 with 100 ppm (by weight) moisture at 70 degrees °F and 45,000 ppm (by weight) mineral oil 525 sus vis. nominal and 0.35 grams of air per pound CFC-12.

10.4.2 High moisture contaminated sample shall consist of CFC-12 vapor with 1,000 ppm (by weight) moisture.

10.4.3 High oil contaminated sample shall consist of CFC-12 with 200,000 ppm (by weight) mineral oil 525 sus vis nomial.

10.5 Test cycle

10.5.1 After pre-conditioning as stated in 8.3, the test cycle is started processing the following contaminated

10.5.1.1 30 pounds (13.6 Kg) of standard contaminated CFC-12.

10.5.1.2 2.2 pounds (1 Kg) of high oil contaminated CFC-12.

10.5.1.3 10 pounds (4.5 Kg) of standard contaminated CFC-12.

10.5.1.4 2.2 pounds (1 Kg) of high moisture contaminated CFC-12.

10.6 Equipment operating ambient

10.6.1 The CFC-12 is to be cleaned to the minimum purity level, as noted in 2.0 and 3.0, with the equipment operating in a stable ambient of 50, 70 and 120 degrees °F and processing the samples as defined in 8.5.

10.7 Sample certification

10.7.1 The cleaned sample of CFC-12 is to be subjected to a quantitative determination of the moisture content by Karl Fisher titration.

10.7.2 The amount of oil in the cleaned sample of CFC-12 is to be determined by gravimetric analysis.

10.8 Quantitative determination of moisture

10.8.1 The apparatus employed is a Karl Fischer coulometer with stirrer, an automated instrument for precise determination of small amounts of water. The weighed sample of liquid CFC-12 is introduced directly into the analyte of the Karl Fischer coulometer. A coulometric titration by the instrument is conducted and the results are calculated and displayed as parts per million moisture weight.

10.9 Determination of percent oil

10.9.1 A weighted, 100 ml sample of the liquid CFC-12 is placed in a pre-weighted graduated Goetz phosphorous tube of 100 ml nominal capacity. The sample and containing tube is maintained in ambient air at a minimum temperature of 90 °F above the expected boiling point of the refrigerant. With the 85 ml of the sample evaporated, the tube is then immersed in a refrigerated brine bath at a temperature of 50 degrees °F above the boiling point of the sample for 30 minutes. The residual sample, if any is allowed to reach room temperature. The tube is reweighed and calculated as percent.

11.0 Non-condensable gas

11.1 The reclaimed CFC-12 sample must be checked by laboratory weight method to determine that the sample does not exceed 0.15 grams of non-condensable gas per pound of refrigerant.

11.2 The equipment must have a device, as defined in 5.3, that will indicate if the external, portable storage vessel, used for the reclaimed CFC-12 has been evacuated, prior to transfer.

12.0 Sample requirements

12.1 Sample must be taken and certified as defined in 4.0, 10.7, 10.8 and 11.0 at each operating temperature as defined in 10.61. Reporting of results, will be used to establish equipment service schedules, to assure the equipment will provide clean CFC-12 in the field.

C) **J1991 Reclamation of CFC-12 used in Mobile Air Conditioning Systems for Cleanliness.**

1.0 Scope:

Due to the CFCs damaging effect on the ozone layer reclaim of CFC-12 used in mobile air conditioning systems is required to reduce system venting, during normal service operations. Establishing reclaim specifications for CFC-12, will assure that sysem operation with reclaimed CFC-12 will provide the same level of performance as new refrigerant.

Extensive field testing with the EPA and the auto industry indicate that reuse of CFC-12 can be considered, provided that the refrigerant is cleaned to a specific standard. The purpose of this recommended practice, is to establish the specific minimum levels of CFC-12 purity, required for reclaimed CFC-12 for use in mobile automotive air conditioning systems.

2.0 Specification

2.1 The standard of purity shall be reclaimed and recycled CFC-12 refrigerant for use in mobile air conditioning systems shall not exceed:

2.2 Moisture - 15 parts per million by weight

2.3 Lubricant - 4000 parts per million by weights of mineral oil based lubricant

2.4 non-condensable gas - 0.15 grams of non-condensable gas per pound of refrigerant.

3.0 Refrigeration Reclamation Equipment

3.1 Moisture and acid -

Incorporate a desiccant package that must be replaced when saturated with moisture and whose acid capacity is at least 5% (percent) by weight of total system dry desiccant.

3.2 Filter -

Incorporate an in line filter of 15 microns or less

3.3 Non-condensable Gas -

If the equipment has a self contained recovery tank. A device to alert the operator that the non-condensable level has been exceeded is required. When external portable tanks, which must have a device that will not permit transfer of the recycled refrigerant to the tank unless the tank has been evacuated.

3.4 Transfer of recycled refrigerant.

Recycled refrigerant for recharging and transfer shall be taken from the liquid phase only.

4.0 Equipment Specification

4.1 The equipment must meet J1990 extraction equipment for automotive air conditioning systems.

4.2 Equipment Certification

4.2.1 The equipment must be certified by underwriters laboratories or an equivalent certifying laboratory.

APPENDIX 4: RIGID FOAM

(see also Appendix 2, Domestic Refrigeration/Freezers)

Dow Chemical, 3035 Orlando Drive, Mississauga, Ontario L4V 1L6

Contact: Dan Crothers, Commercial Director for Construction Materials
(416) 673-4274

Business: Manufacture foam insulation products for building construction

CFC Interests:

- Were using CFC 12 for blowing foam but have recently started to use HCFC 22 and are not concerned at this point with capture technology.

  In independent correspondence sent by Dow to the MOE(Brendan Killackey in December, 1988), Dow revealed the quantity of CFC 'banked' in their styrofoam™ products as follows:

Years from date of manufacture:	Initial	1	5	10	20	30
% CFC 12:	80	79	77	74	69	64

  These were presented as weighted averages for typical product/size mix which includes initial losses when product is extruded and trimmed and the excess material reprocessed.

APPENDIX 5: FLEXIBLE FOAM

Canadian Flexible Foam Manufacturers Association

6900 Airport Road, Suite 200, P.O. Box 85, Mississauga, Ontario
L4V 1E8

Contact: Environmental Committee (416) 677-6561

Purpose: Have 14 corporate members. Some member companies involved in environmental committee which looks at items such as CFC reduction in plant.

Curon Canada, 415 Evans Avenue, Toronto, Ontario M8W 2T2

Contact: Craig Barkhouse (416) 259-8431

Business: Produces flexible foam polyurethane products for upholstery market; produce average of 8 different types of foam/day.

CFC Interest:

- Use CFC 11 and MeCl as auxiliary blowing agent
- Would like to see HCFC use in the future
- Have drastically reduced CFC use by changing consumption patterns
- Turnaround time is 2.5 days (warehouse full of foam product)

Production Process:

- Pour 500 lbs/min, 160 ft of conveyer area
- Moves 20 ft/min; very high air flow reduces vapour levels inside (30,000 cfm through fans, with 7-8 fans)

CFC losses:	Point of Pour:	25%
	1 hour	40%
	2 hours	19%
	3 hours	9%
	4 hours	4%
	5 hours	2%
	6 hours	1%

In first 60 ft (3 mins) lose the lions' share, foam gels in different stages:
liquid
viscous liquid
semi gel
starts to solidify
solidified to pull sides off foam

Craig Barkhouse is on the UNEP committee for CFC reduction on flexible foam.

Potential Blue Bottle™ Uses:

- Could see use of Blue Bottle™ in capture system, especially when VOC emissions become critical
- Carbon adsorption has been used with some success in Europe to capture emissions with sacrificial up front area which becomes contaminated with isocyanates, etc., although fouling has not been a great problem according to the researchers

APPENDIX 6: SOLVENTS

Northern Telecom

Contact: Art Fitzgerald, Corporate Director for Environmental Concern
(416) 897-9000 ext. 3048

Business: Leading global supplier of fully digital telecommunications switching systems. Manufacturers of telephones, business terminals cable, small and large telephone switching equipment and other apparatus. Revenues in 1988 worldwide were $5.4 billion. Have 23 plants in Canada.

CFC Interests:

- Have one company-wide program to reduce consumption
- Uses CFC 113 as cleaning compound to remove solder residue from printed circuit boards
- Had begun in 1988 a 3 year phase-out program for 113
- Became first electronics manufacturer in the world to announce a CFC phase-out
- Is involved in the U.S. Navy China Lake testing projects and is a principal contributor (i.e. the ad hoc committee formed by U.S. military, government and industry to rewrite military specifications for the cleaning of printed circuit boards and assemblies
- Member of UNEP Solvent Options Committee and peer reviewer on UNEP Halon Technical Options Report
- Confirmed alternative discharge methods for halon fire extinguisher systems in a project with National Fire Protection Association
- Drafted a manual on CFC management practices to be published by EPA for small and medium sized users of 113
- Founding member of new Industry Cooperative (i.e. ozone layer protection) to help transfer CFC solvent elimination technology globally (includes AT & T, Boeing, Digital Equipment Corp., Ford Motor Company, General Electric, Honeywell, Motorola and Texas Instruments)

CFC Reduction Program:

- Completed company-wide survey in 1988 to find quantity of CFC consumed and how it was used; also inventoried all equipment using CFCs
- Also evaluated Halon 1211 hand-held fire extinguishers and 1301 total flooding systems to evaluate volume of both
- Found 97% of CFC use was with 113
- Found they could reduce 40-50% by using simple conservation techniques
- Alternate technologies also considered for more permanent solutions:

(1) alternate solvents: terpenes, aqueous cleaning, also soldering under controlled atmosphere (will be using the technology for limited applications)

(2) using low solids/no clean fluxs (suitable for 80-85% of product manufacture

- Eliminated CFC use in foam blowing for packaging in 30 days
- Are presently collecting halons not designated for essential use in 2 sites - for destruction and limited amount for research (sample coming to ORTECH)

  (Their insurance company agreed that, in any single installation, if it affects less than $10 million worth of business, then aqueous fire control systems will be used)
- Working with a combustion engineering group to evaluate use of porphorins as part of potential CFC destruction technology

Northern Telecom Canada Ltd., 5550 Skyline Way N.E., Skyline Industrial Park, Calgary, Alberta T2E 7Z7

Contact: Todd Metcalf (403) 221-7566

Business: Manufacture digital telecommunication equipment

CFC Interest:

- Have used carbon adsorption system to collect in use CFC emissions from 3 cleaning lines, bulk delivery area, chemical storage

System Design:

- Use 3 tanks of activated carbon (360 gal per tank SA diameter) per bed of activated carbon; cycle 2 adsorbing, 1 desorbing; desorb every 9 hours (not saturated); capture 90% of emissions. Loading is unknown; 3,800 cfm total volume; sized beds for 5,151 gals (34,000 kg). Room size = 30 x 36 with 1,400 cfm through room; bottom vented (raised floors)
- Alarm limit = 500 ppm (in Ontario, limit is 1,000 ppm); measured concentrations on average = 1.4-1.6 ppm in room
- When unit closes, system reaches 500 ppm in 15 minutes in exhaust
- Claim to have excellent desorption with no noticeable residual in over 9 months of operation (quantitative mass balance not provided)

Freon Management System (FMS) Success Rate:

Year	Total CFC Consumption (kg)	kg CFC/100 M^2 board
1987-88	42,000	180
1988	38,387	150
1989	34,000	130
1990 goal		20

Litton Systems Canada Ltd;, 25 City View Drive, Etobicoke, Ontario M9W 5A7

Contact: Helen Lakusta, Manager, Occupational Safety (416) 249-1231

Business: Many military contracts which need to adhere to military spec requirements, 2,600 employees in 5 buildings

CFC Interest:

- CFCs are used across the production floor for: spot cleaning; cooling; aerosols; degreasing

Degreasing System:

- Have dip tanks (~ 5 ft x 5 ft) with manual sprays and cooling coils to reduce vapour release; no covers in system
- 3 degreasers use = 45 gals/2 weeks for 300 boards/week (in touch up work area) of TES (113 + ethanol blend 0.04%)
- TMS unit (113 + 0.05% methanol), 1 only; 45 gals/2 weeks to top unit up
- 150 boards are rinsed 2 x each
- System is ~ 35 ft long x 15 ft wide x 10 ft high in sectioned off room

Lab tests on incoming CFC - need to check moisture level less than 100 ppm and methanol + ethanol content

Spot cleaning ("Coolit") - 1 lb cans of 113; for one whole section - use 72 cans/month

Fire Extinguishers:

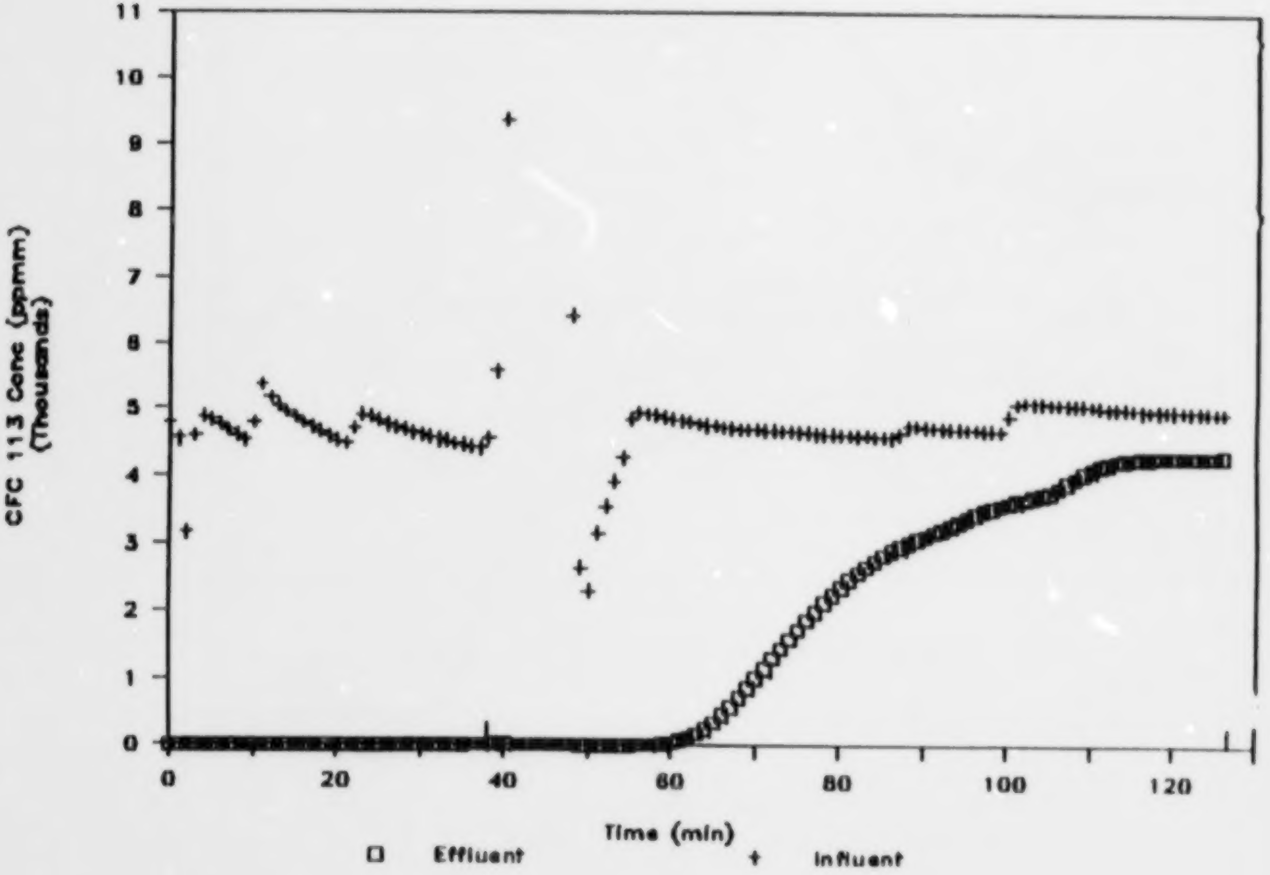
- 1 halon total flooding system for computer room/confined areas
- Several smaller hand held halon canisters available throughout the building
- Concern that CFC in fire could generate HCl which could be corrosive
- Interested in molecular sieve as backup for total flooding system

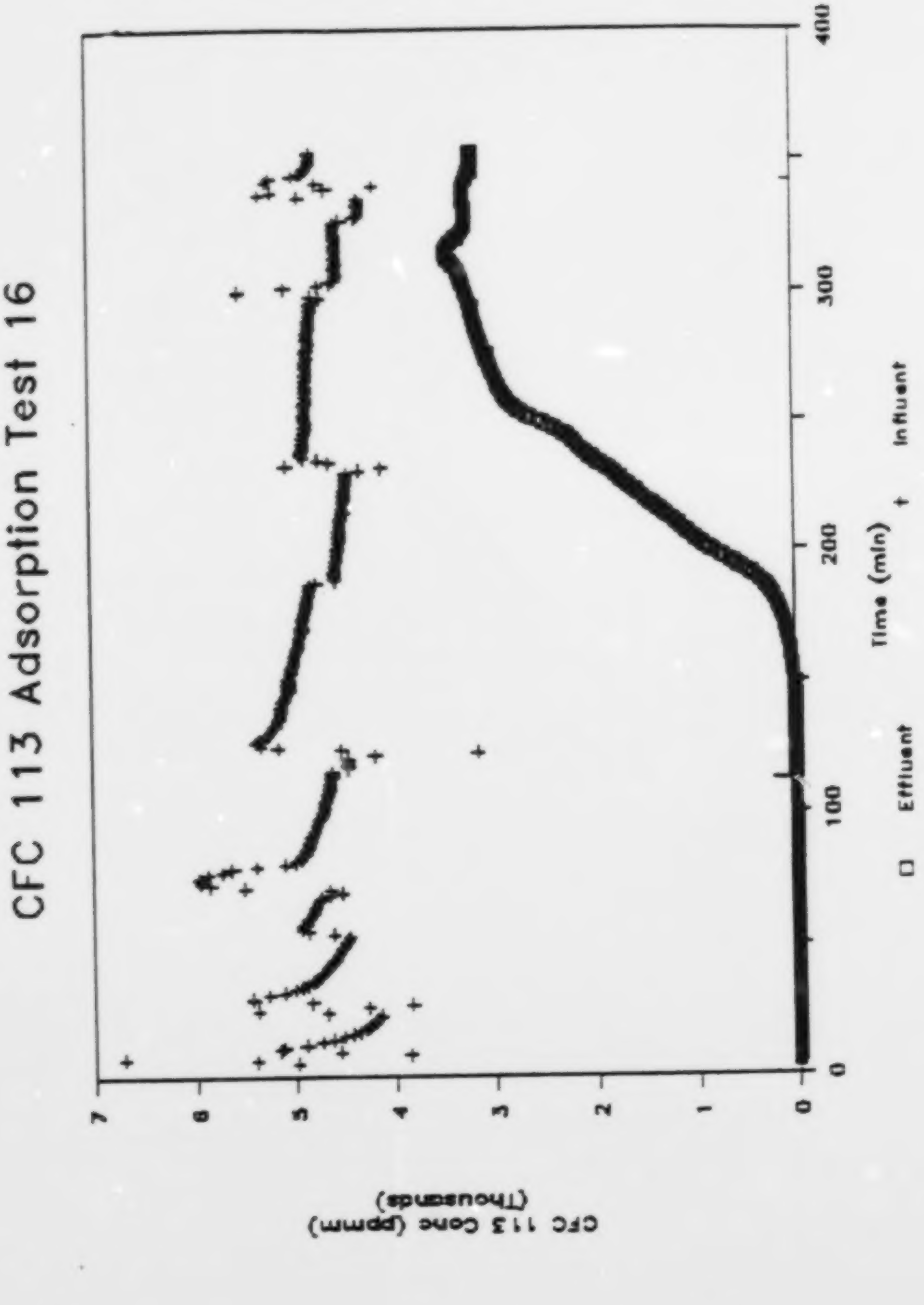
Freon Reduction Group has been formed:

- Sister plant for guidance systems in California is more actively involved in alternatives to CFC study
- Litton is rebuilding sections and would be interested in molecular sieve potential for recovery of CFC should they be continued to be used
- Areas of CFC use could be localized to facilitate collection and recovery

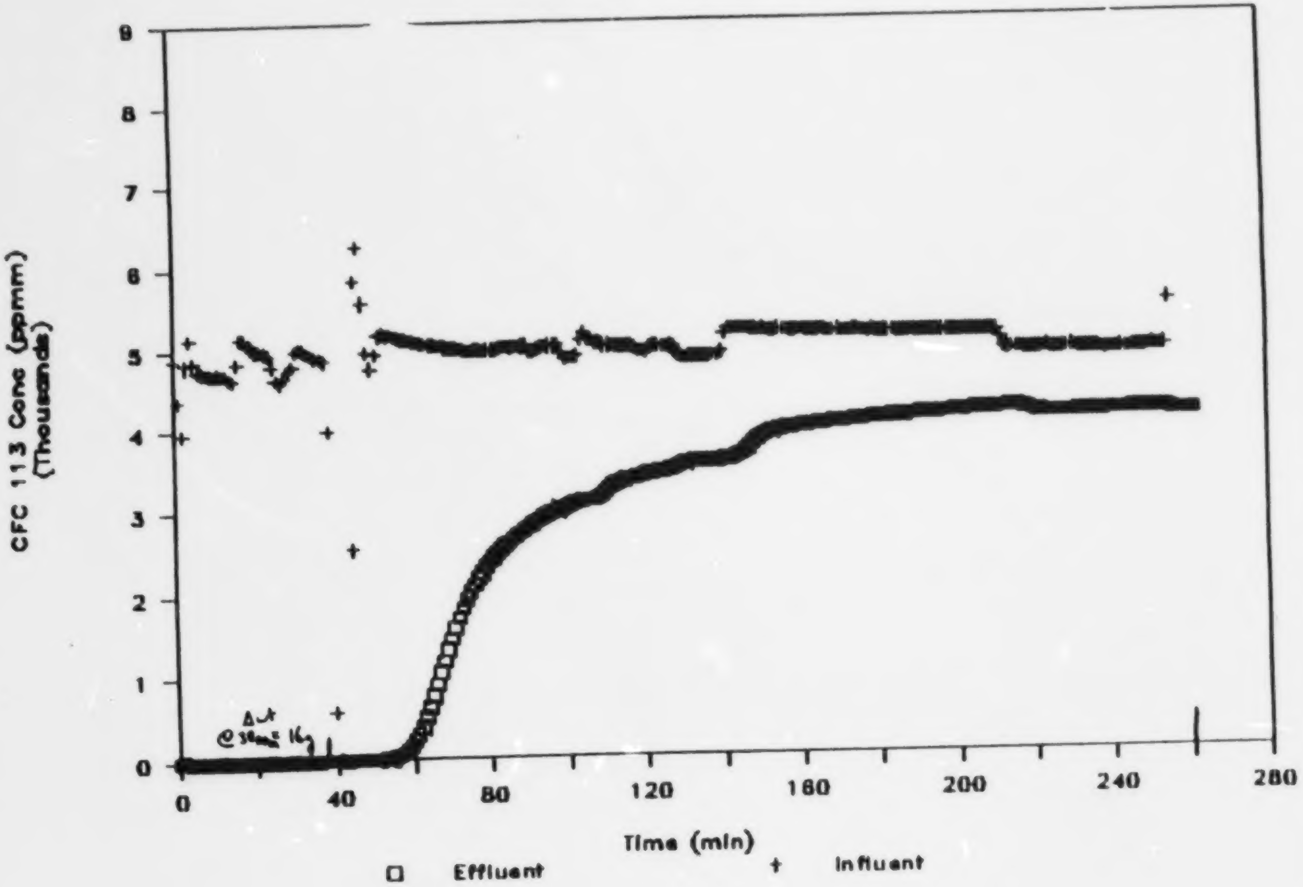
APPENDIX 7: CFC 113 BREAKTHROUGH CURVES

CFC 113 Adsorption Test 15

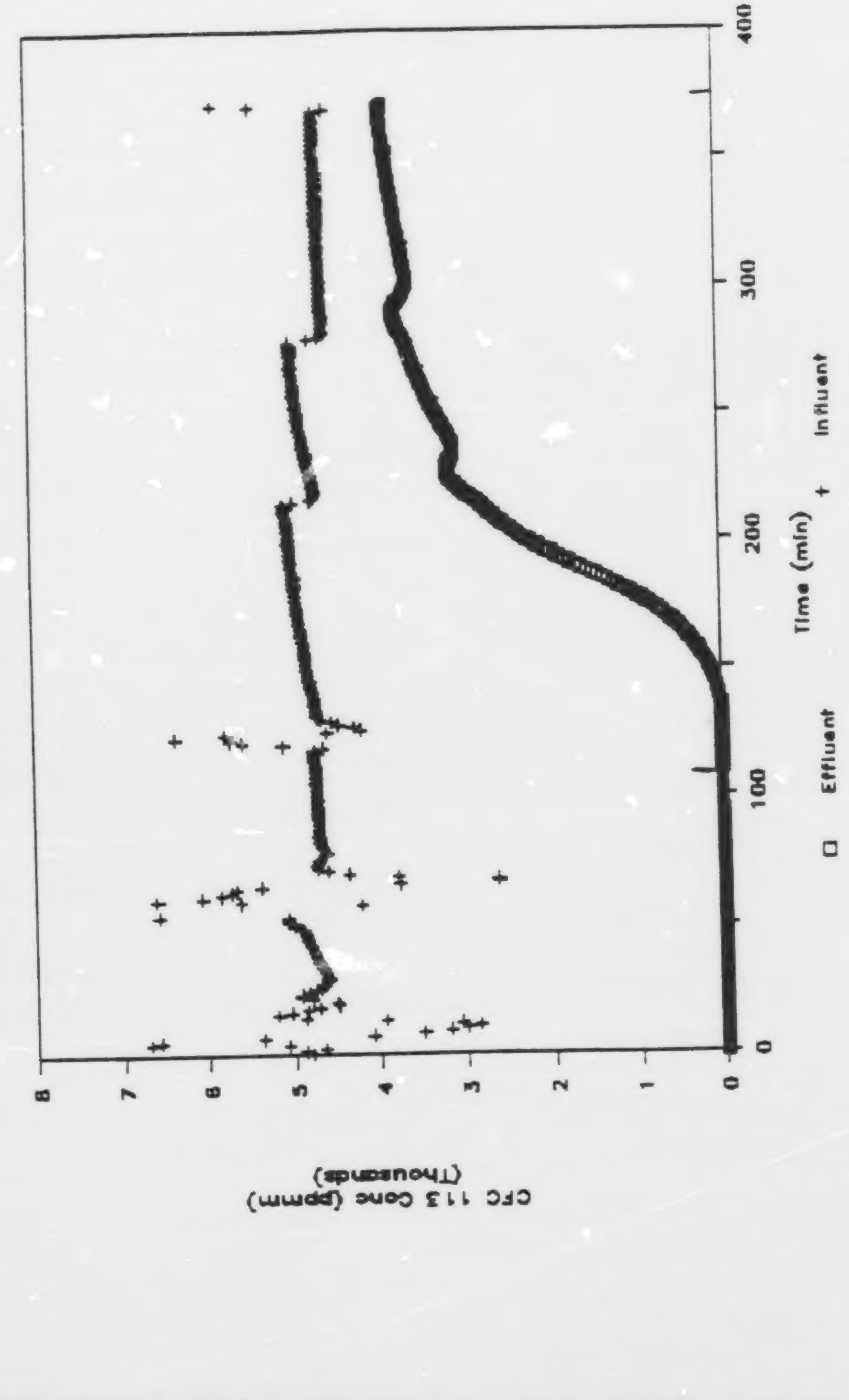


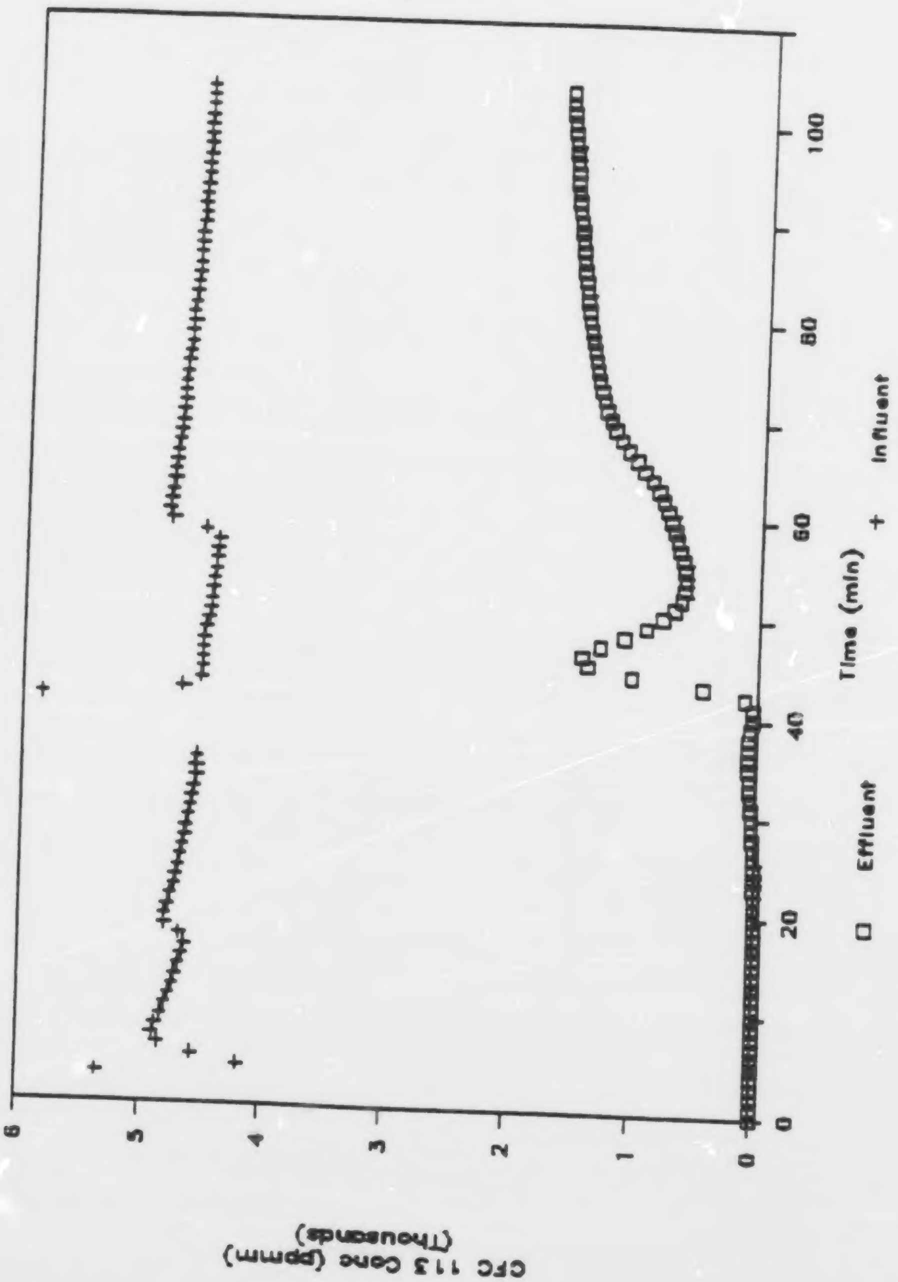

CFC 113 Adsorption Test 16
CFC 113 Conc (ppmm)
(Thousands)
7
6
5
4
3
2
1
0
0
100
200
300
400
Time (min)
□ Effluent
+ Influent

CFC 113 Adsorption Test 17

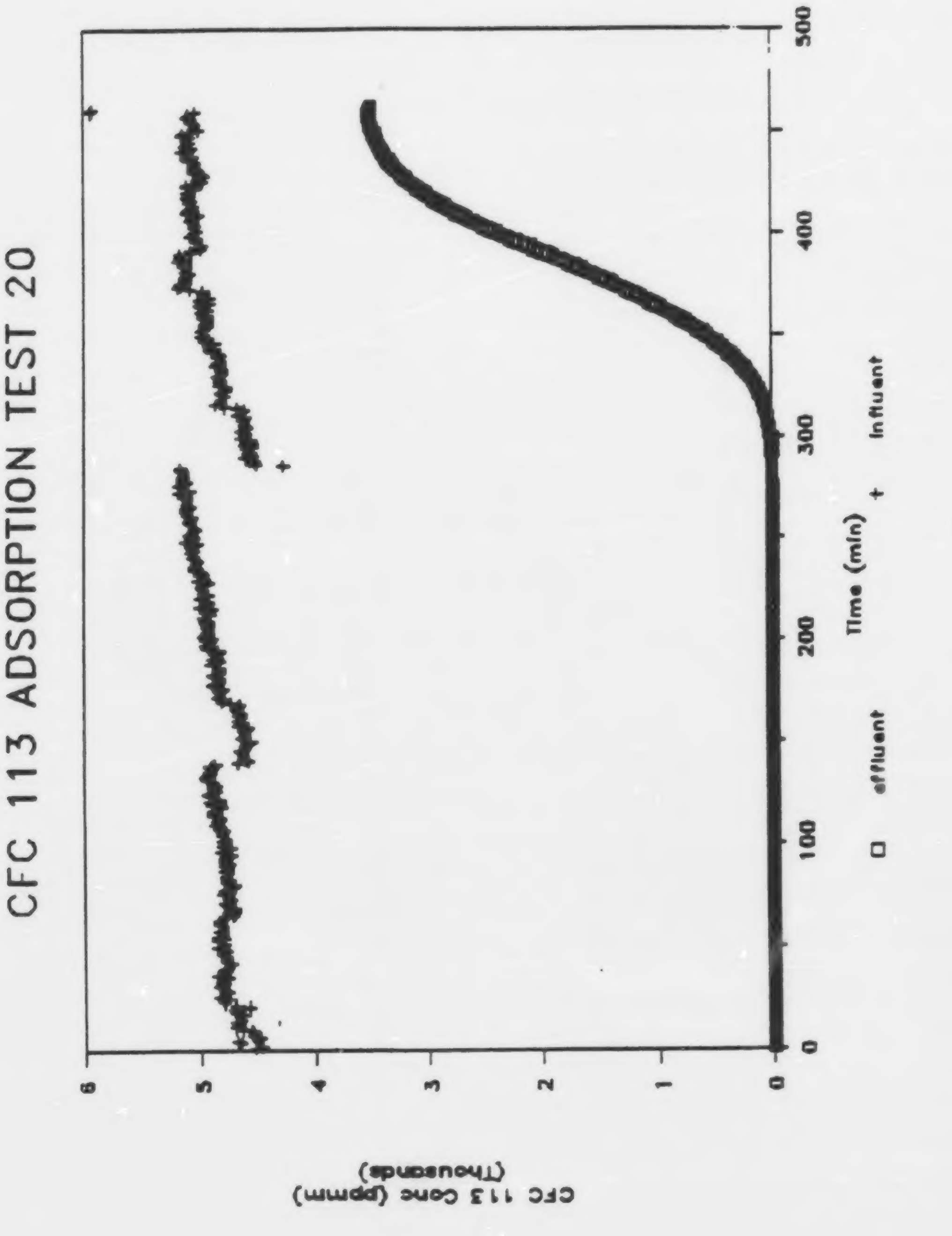


CFC 113 Adsorption Test 18

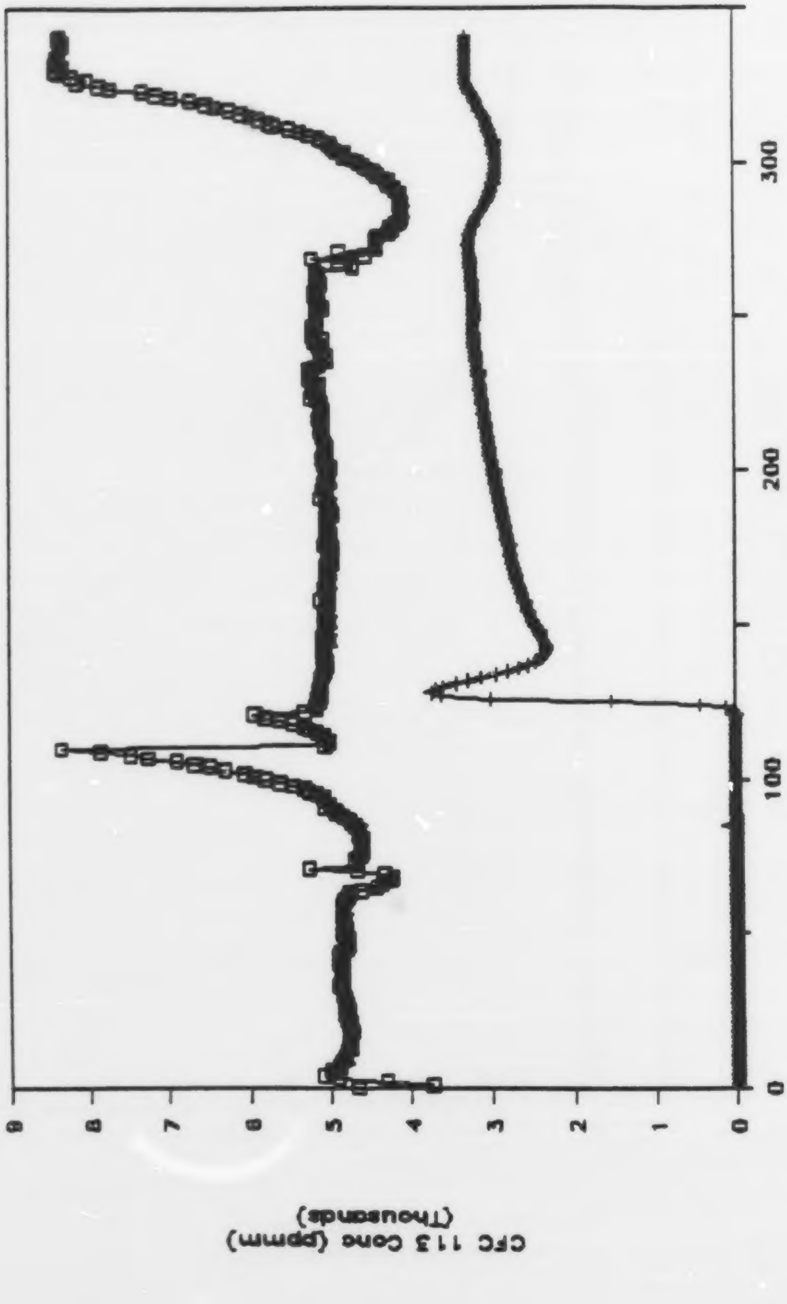


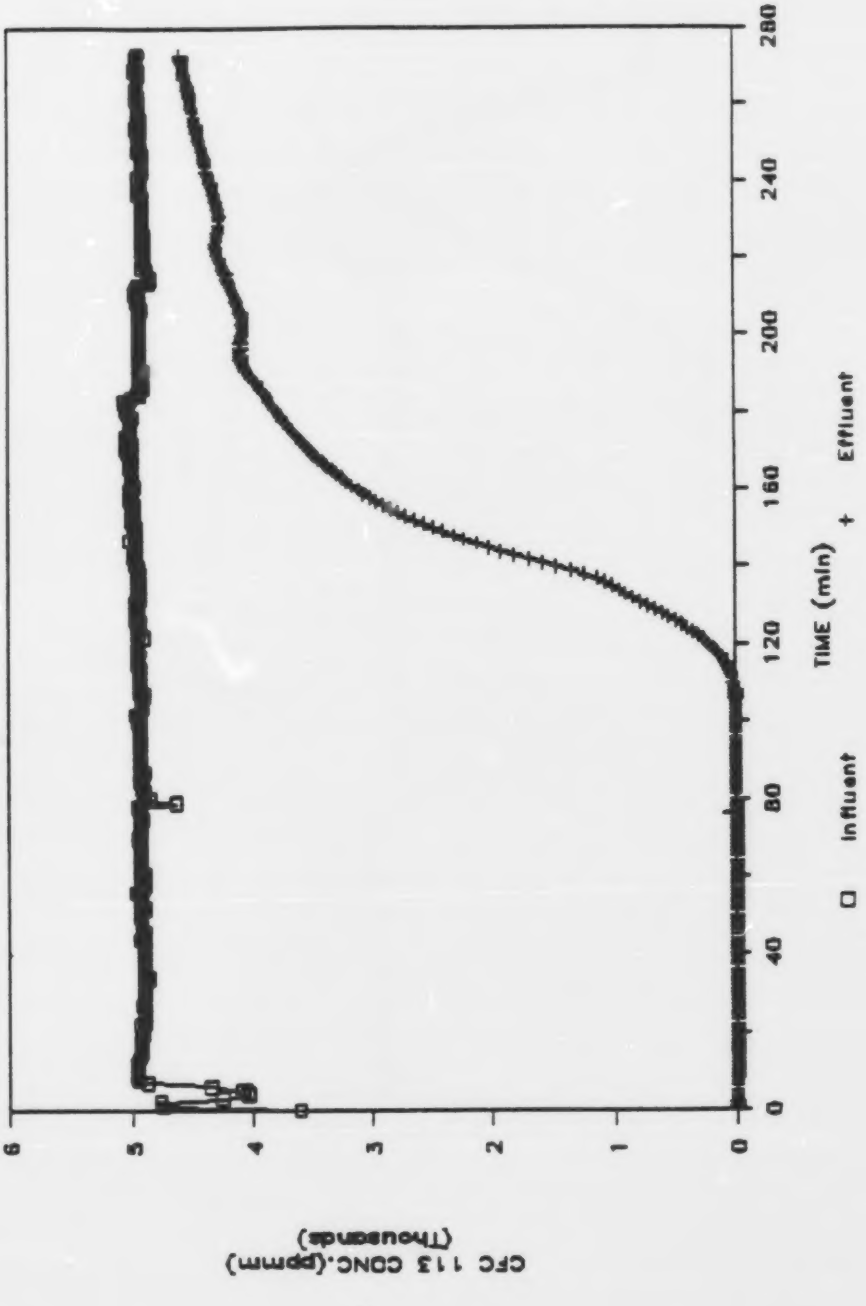


CFC 113 Adorption Test 19


CFC 113 ADSORPTION TEST 20
CFC 113 Conc (ppmm)
(Thousands)
0
1
2
3
4
5
6
0
100
200
300
400
500
Time (min)
□ effluent
+ influent

CFC 113 Adsorption Test 21

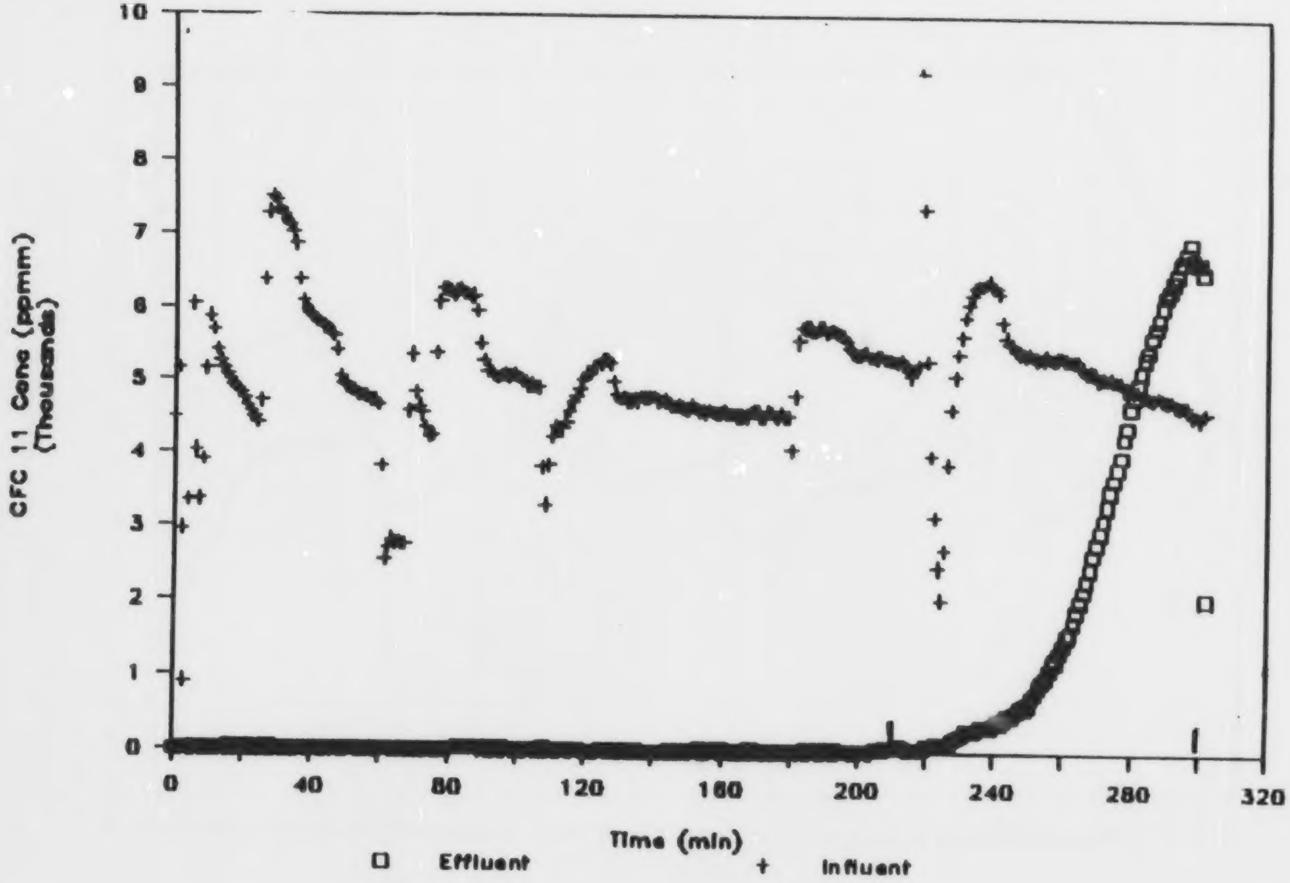


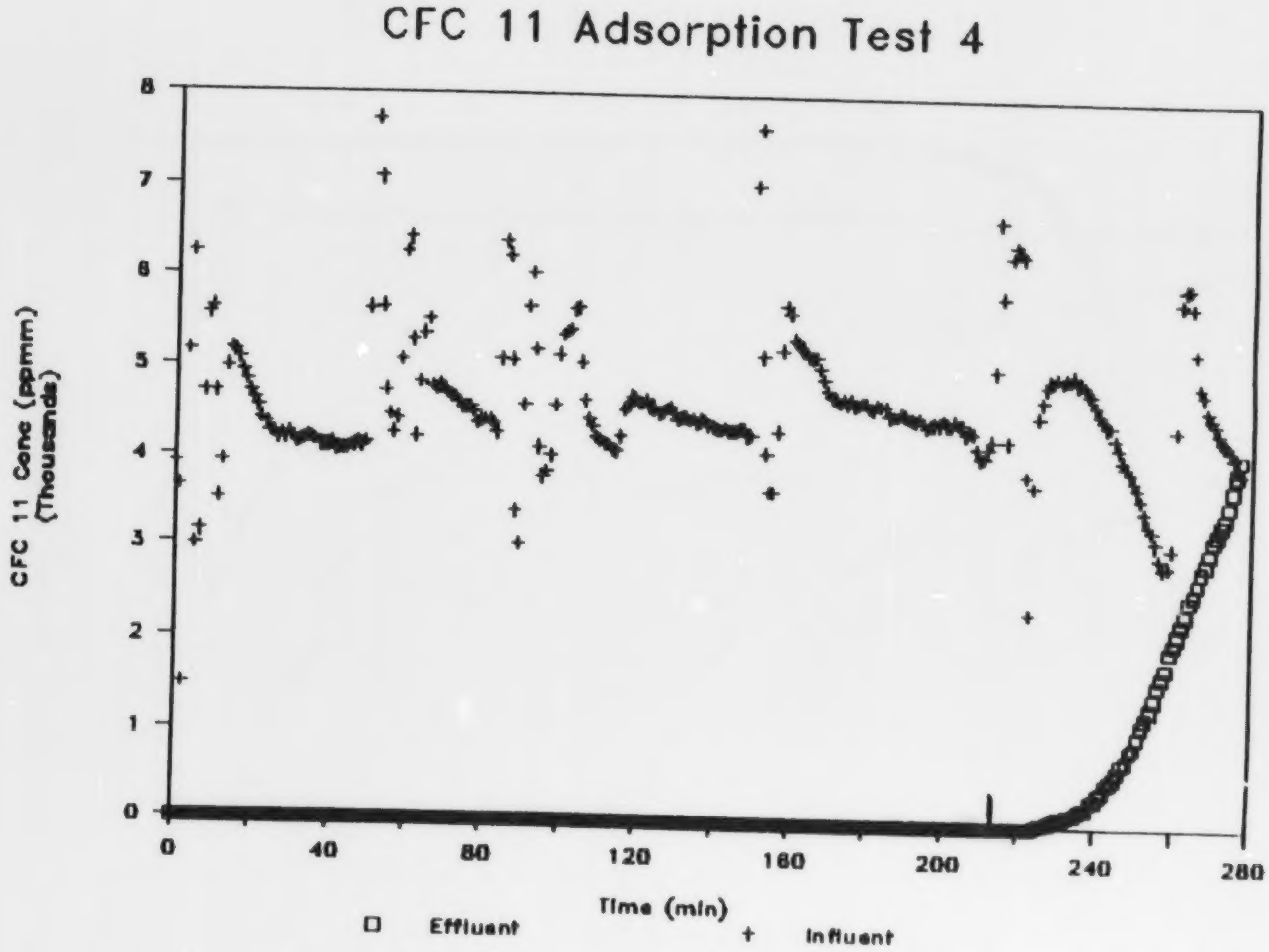


CFC 113 ADSORPTION TEST 22

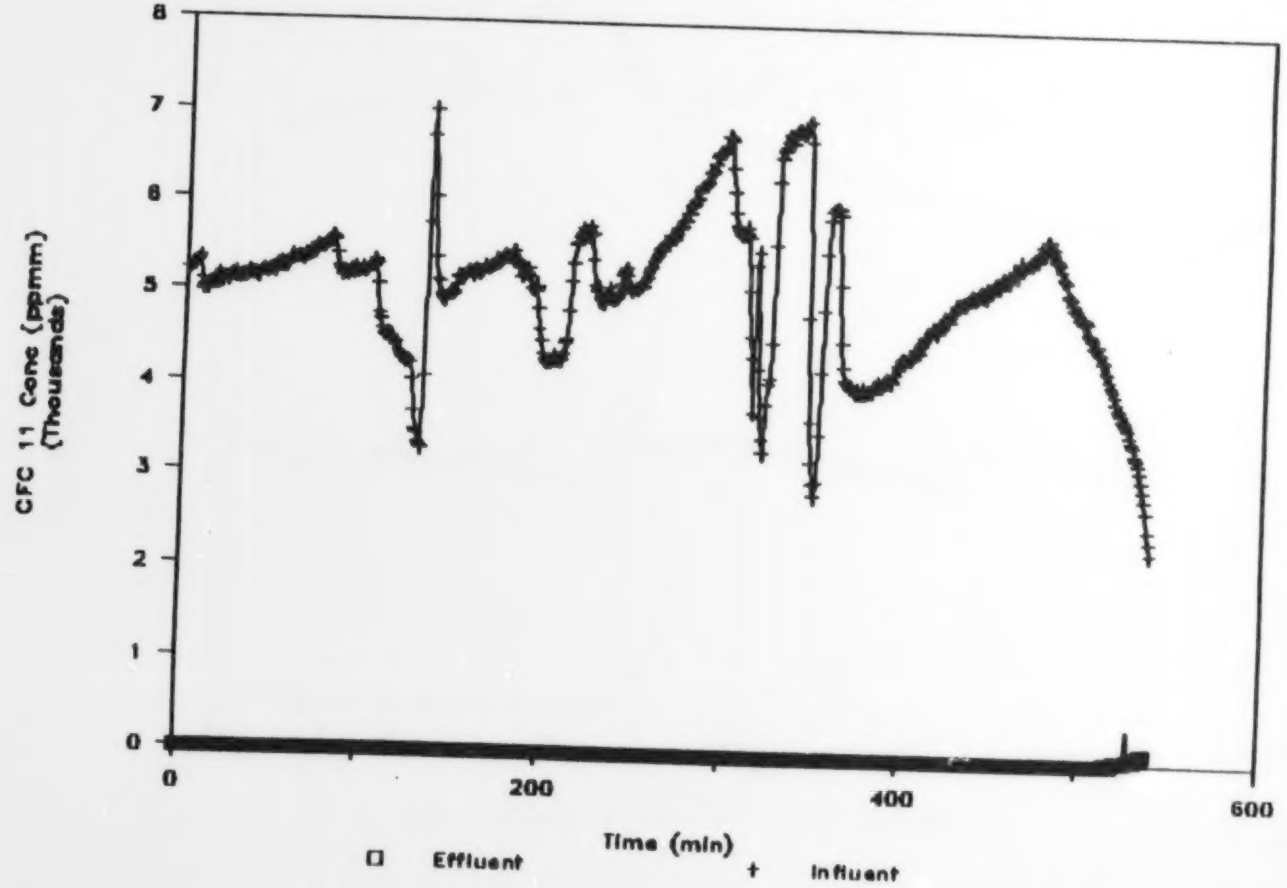
Double Cannister, 5000 ppmm, 12L/min

CFC 11 Adsorption Test 3

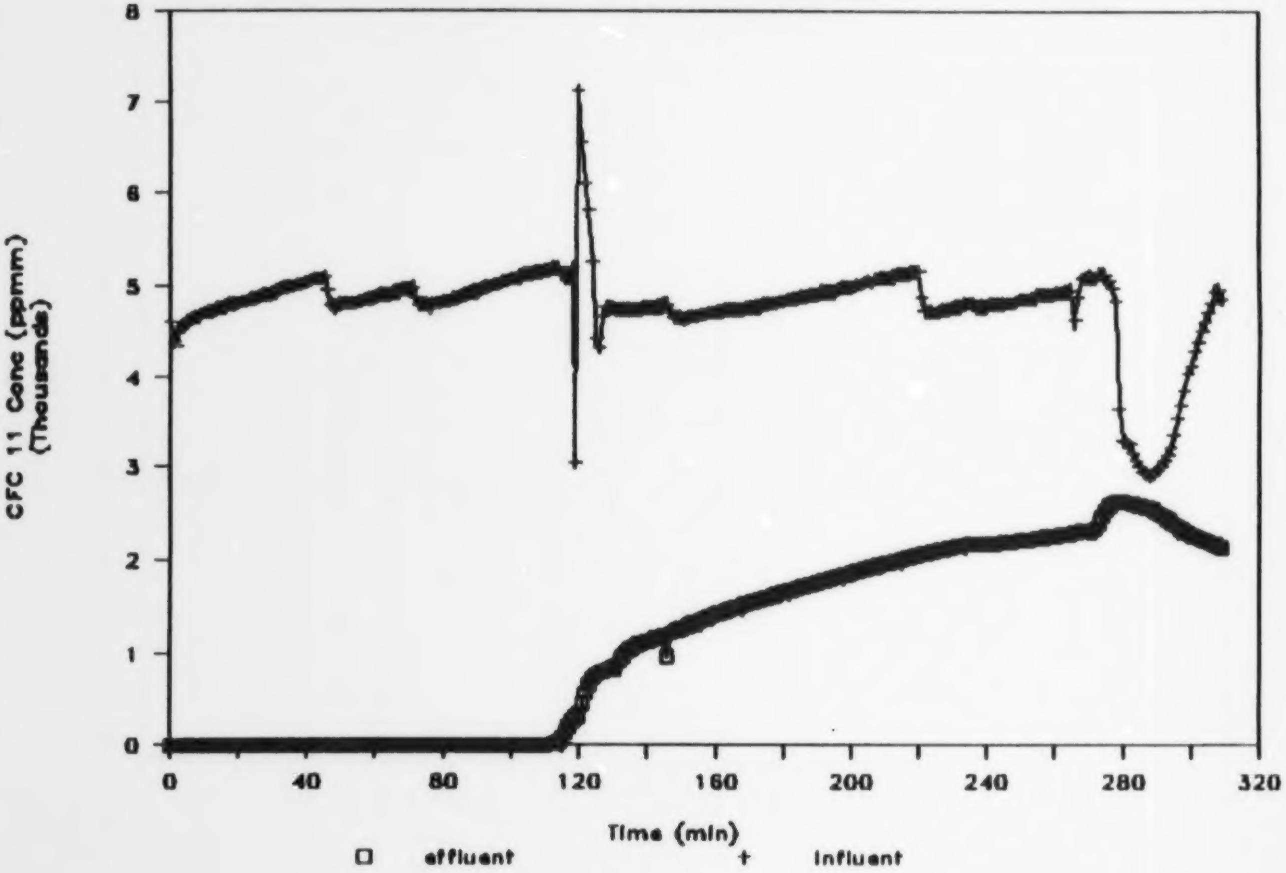


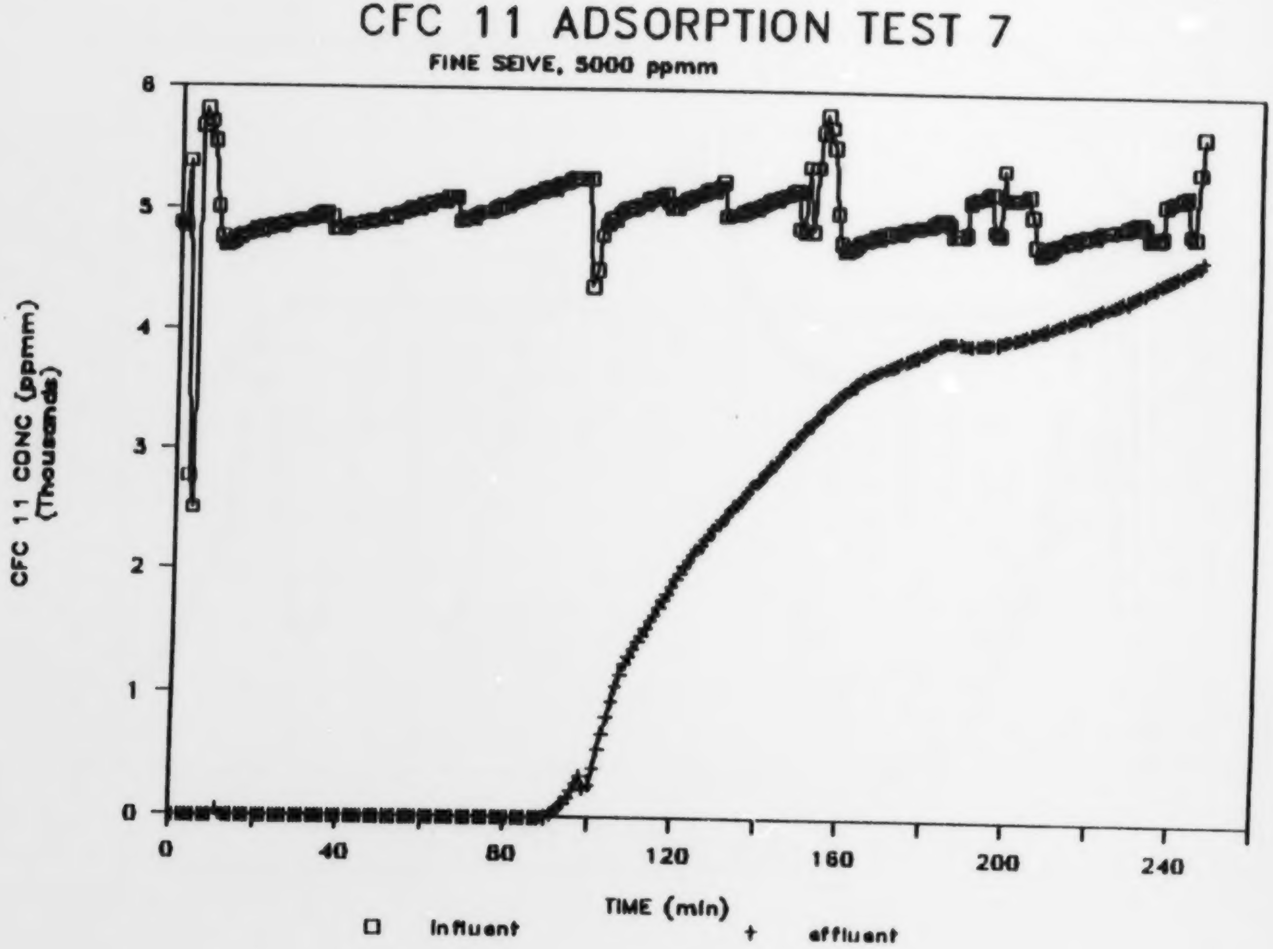

CFC 11 Adsorption Test 4
CFC 11 Conc (ppmm)
(Thousands)
0
1
2
3
4
5
6
7
8
0
40
80
120
160
200
240
280
Time (min)
□ Effluent
+ Influent

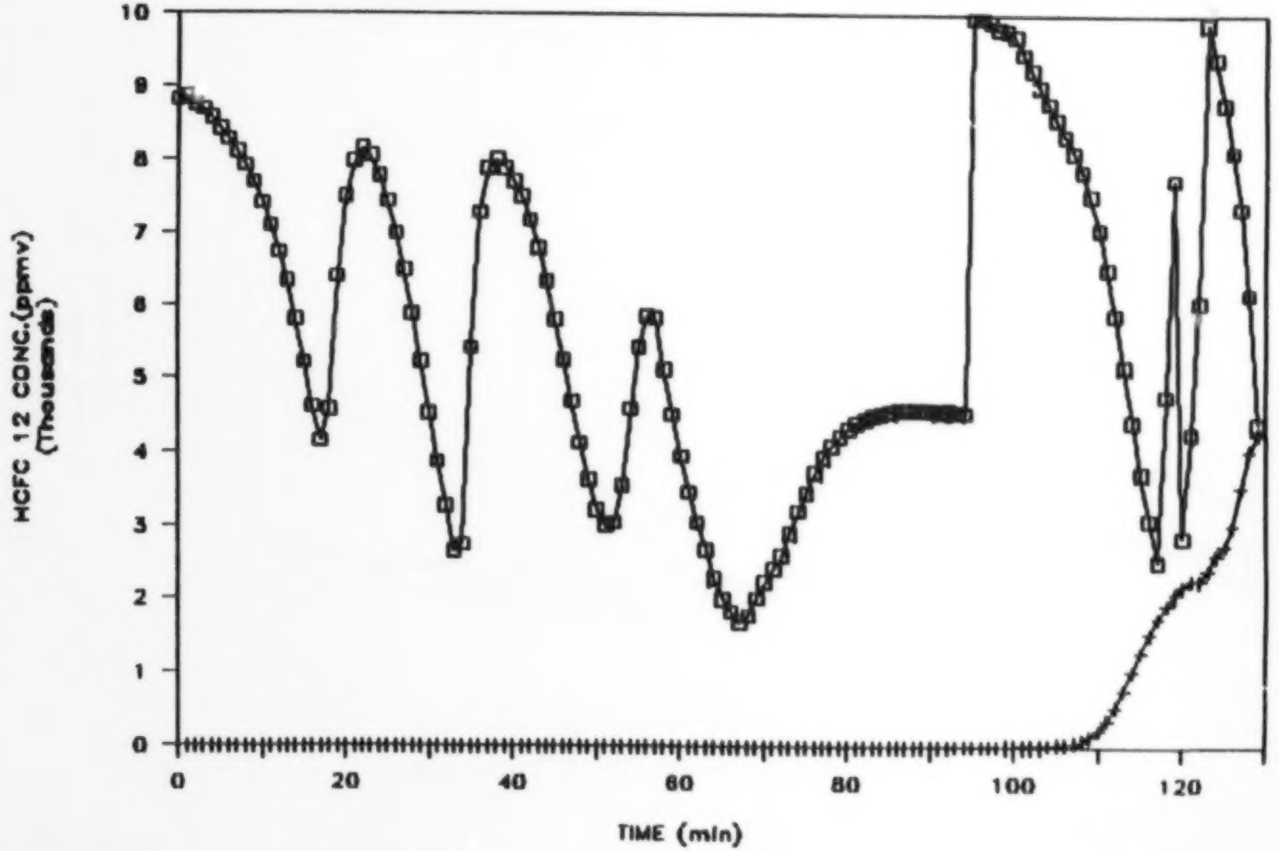
CFC 11 Adsorption Test 5



CFC 11 Adsorption Test 6

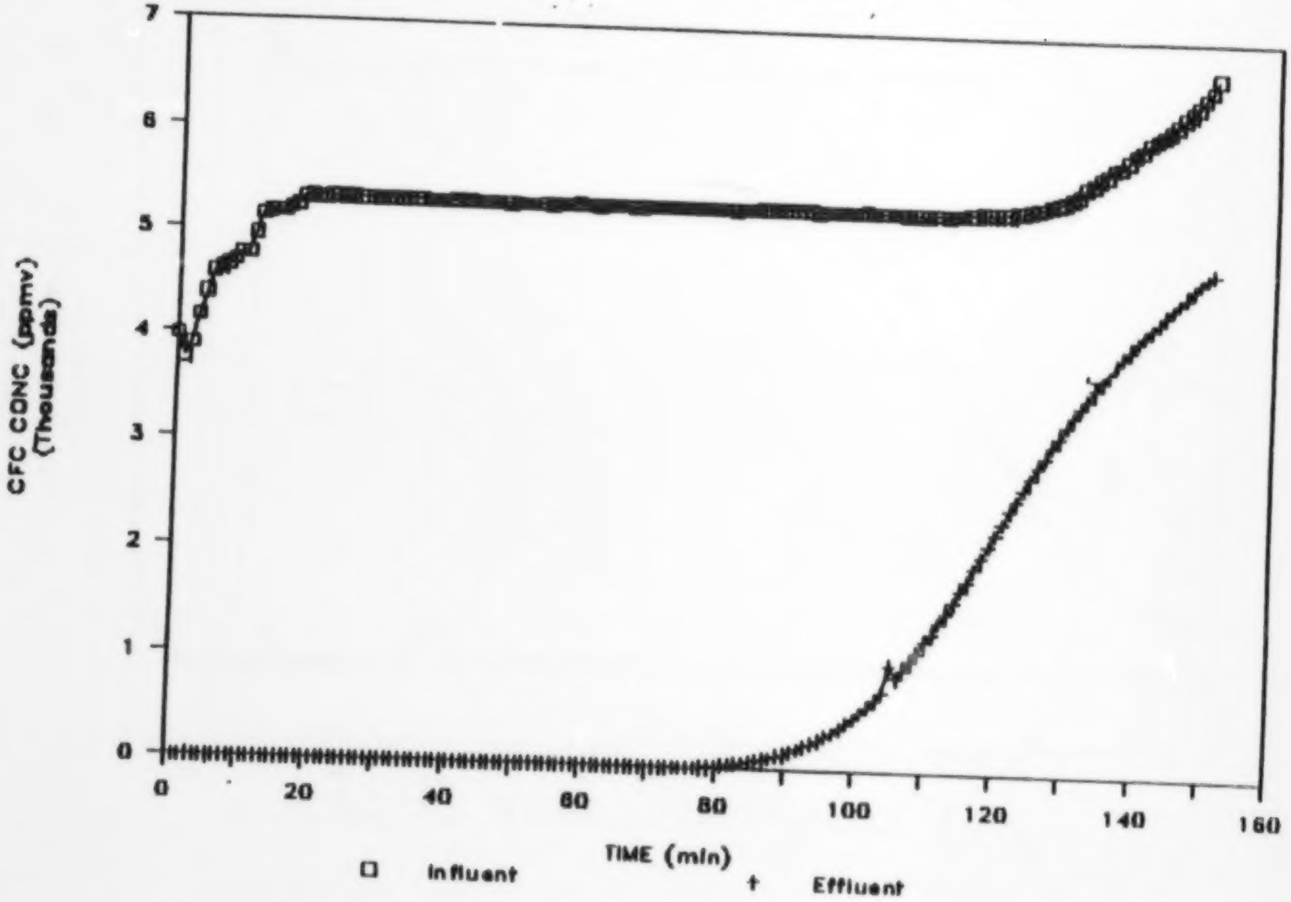


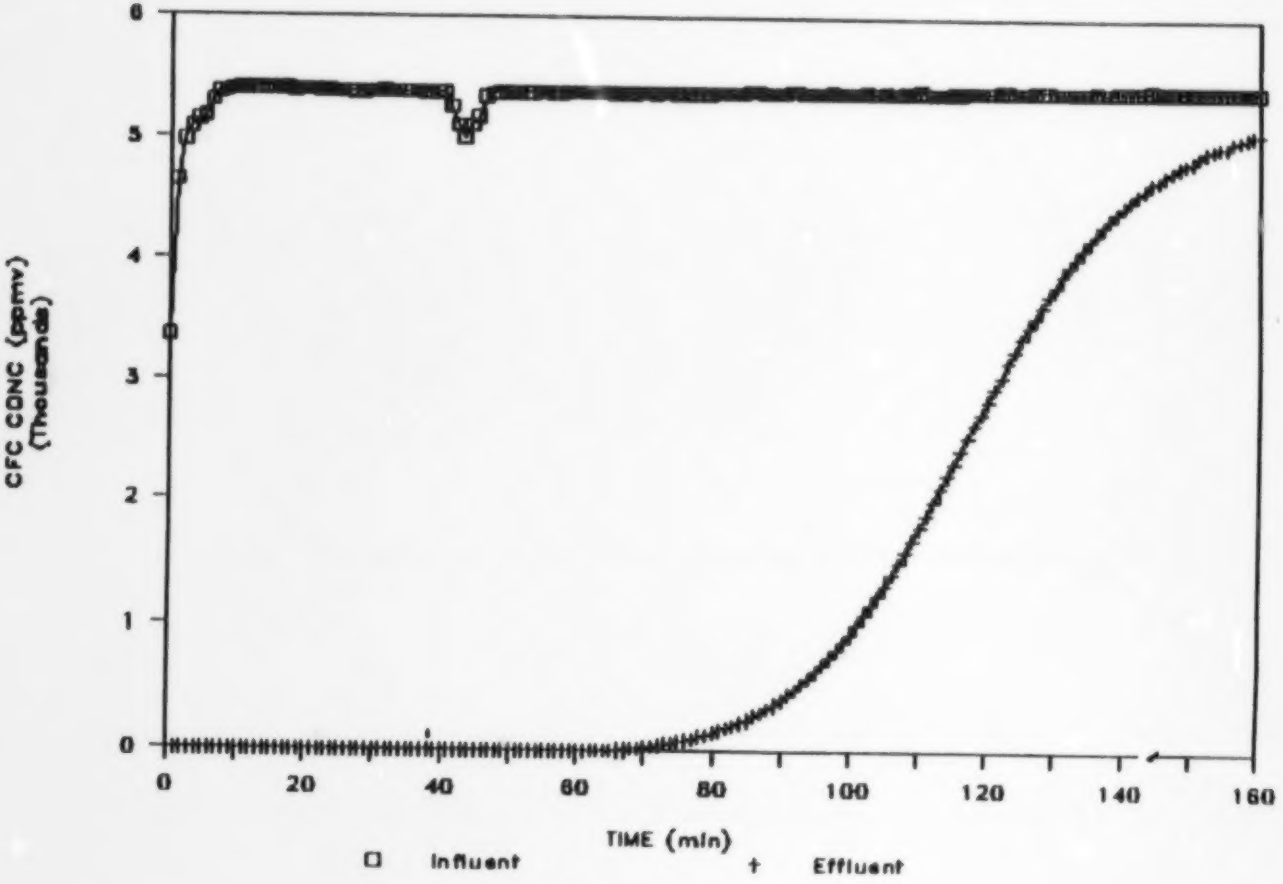

CFC 11 ADSORPTION TEST 7
FINE SEIVE, 5000 ppmm
CFC 11 CONC (ppmm)
(Thousands)
6
5
4
3
2
1
0
0
40
80
120
160
200
240
TIME (min)
□ influent
+ effluent



CFC 12 ADSORPTION TEST 1

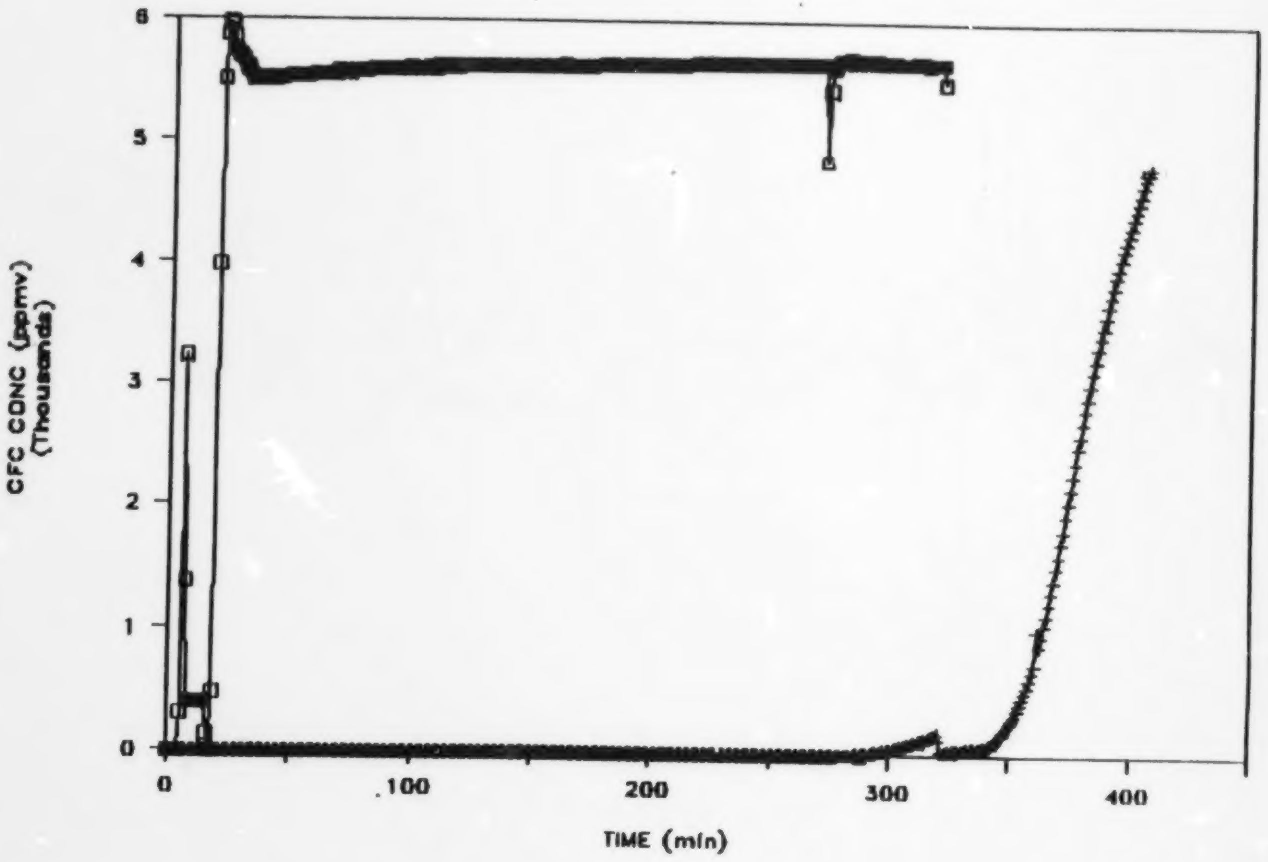
CFC 12 ADSORPTION TEST 2

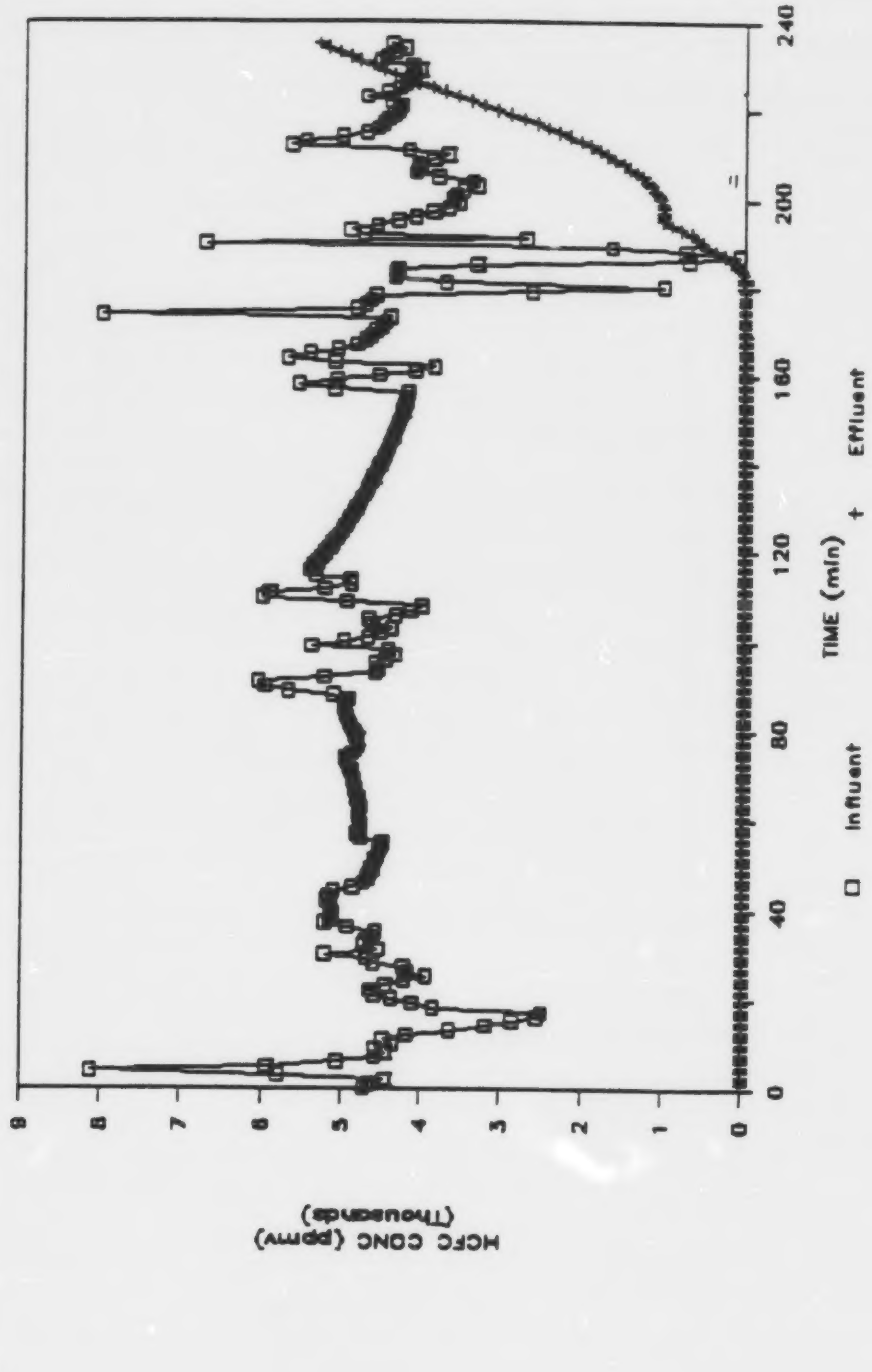




CFC 12 ADSORPTION TEST 3

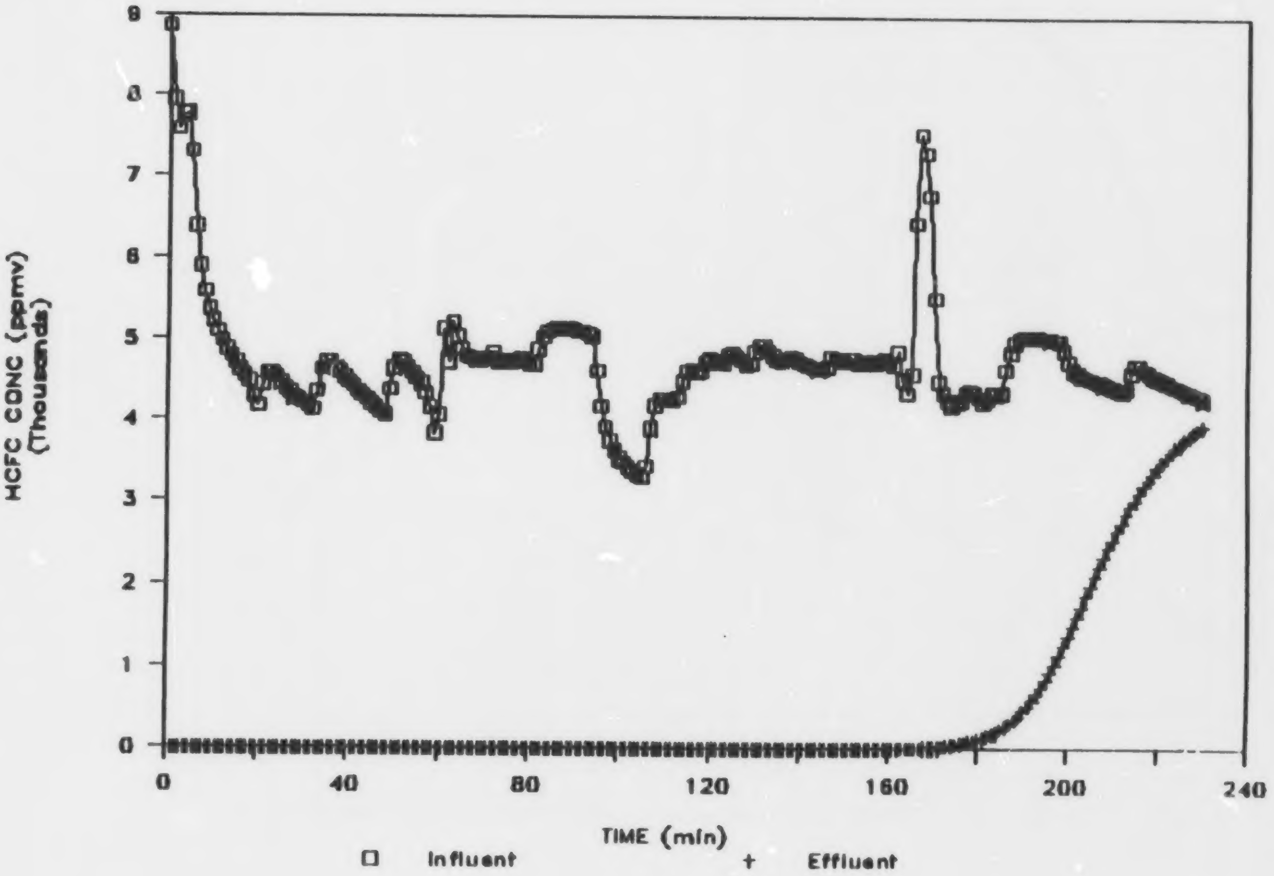
CFC 12 ADSORPTION TEST 6

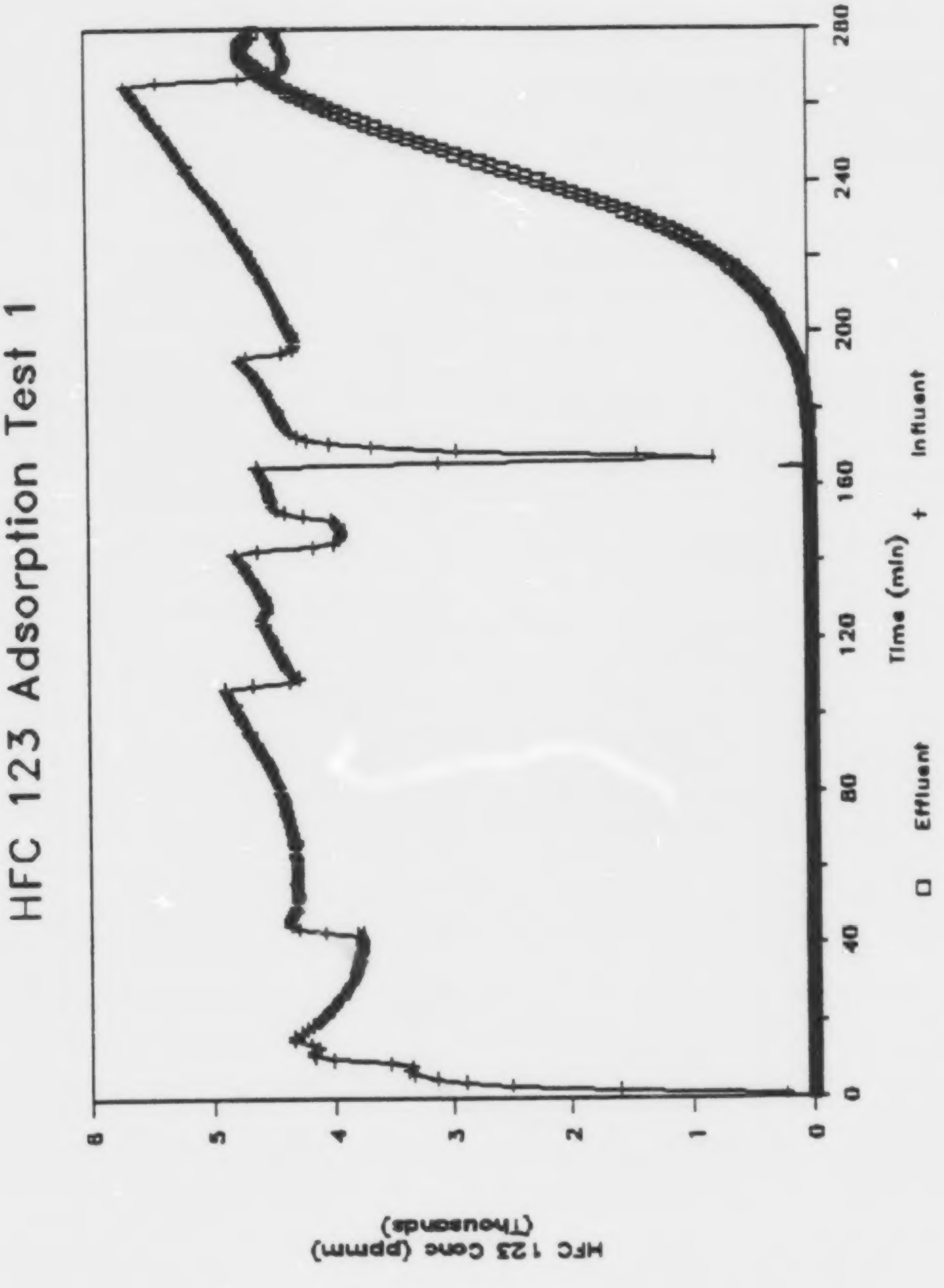


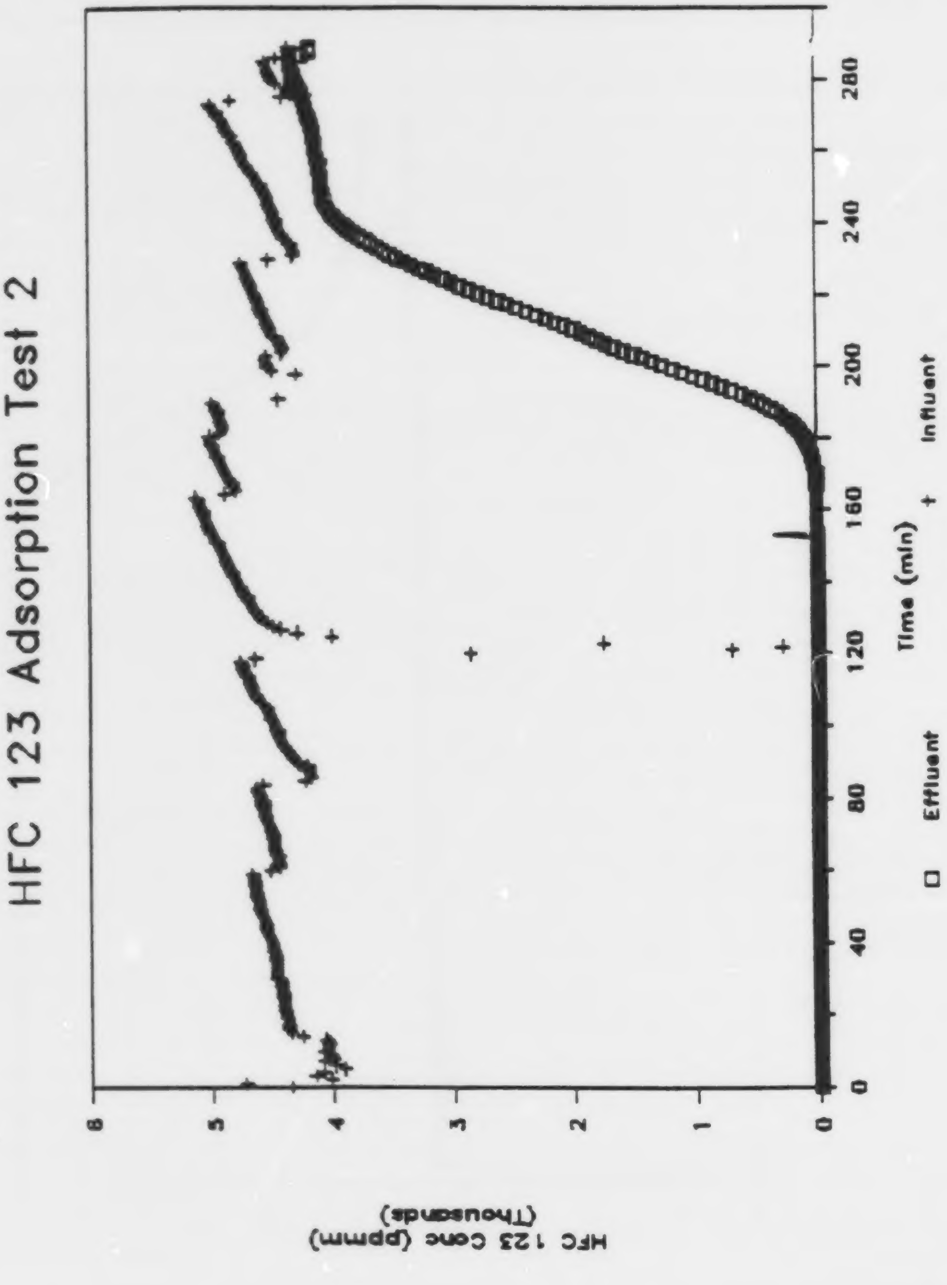


HCFC 22 ADSORPTION TEST 1

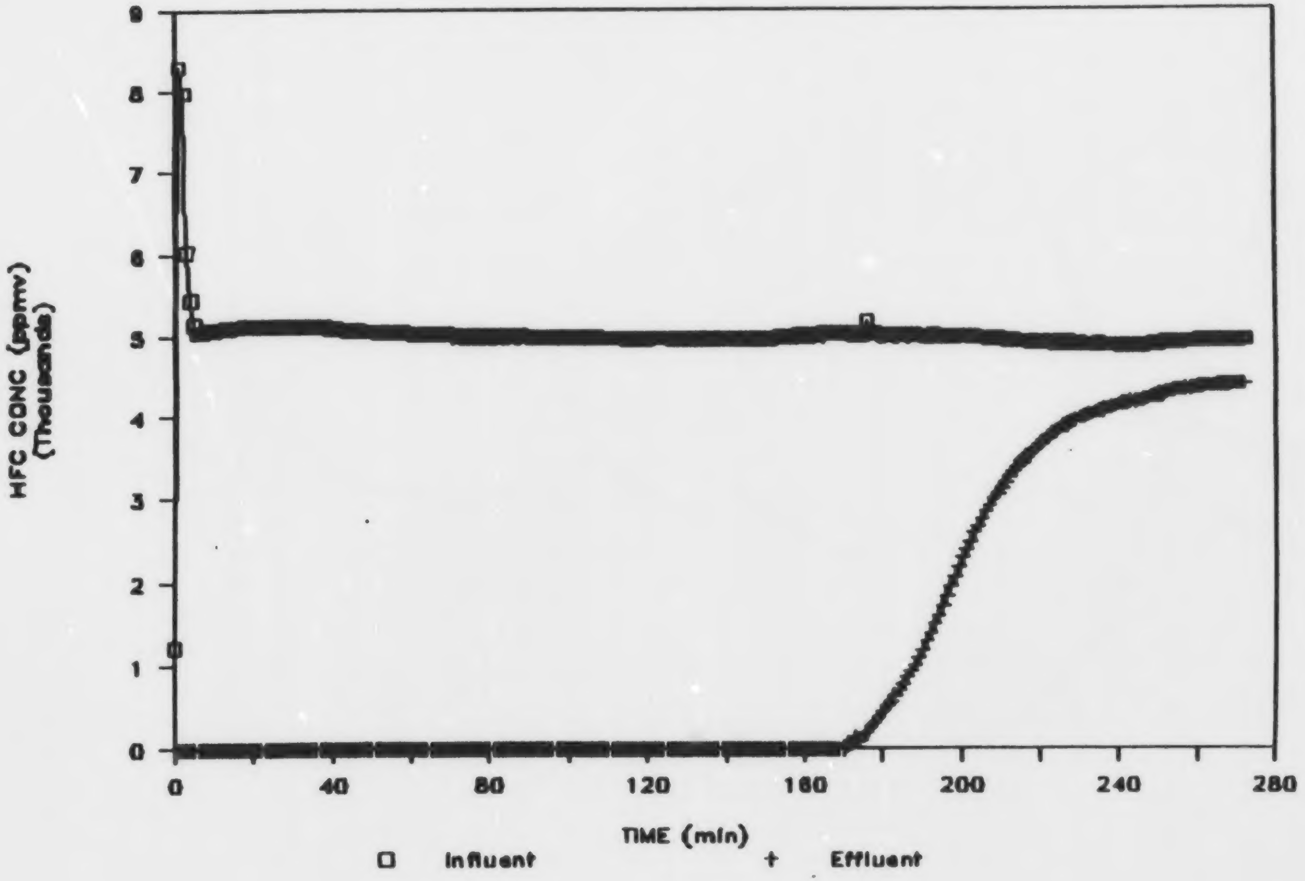
HCFC 22 ADSORPTION TEST 2




HFC 123 Adsorption Test 1
HFC 123 Conc (ppmm)
(Thousands)
6
5
4
3
2
1
0
0
40
80
120
160
200
240
280
Time (min)
□ Effluent
+ Influent


HFC 123 Adsorption Test 2
HFC 123 Conc (ppmm)
(Thousands)
0
1
2
3
4
5
6
0
40
80
120
160
200
240
280
Time (min)
□ Effluent
+ Influent

HFC-134a ADSORPTION TEST 1



APPENDIX 8: CALCULATIONS AND COMPUTER ALGORITHM

CFC Con (ppmm) 100000

Temp (C) 25

Pressure (psia) 14.7

zCFC = 0.1 (mole frac)

zN2 = 0.9 (mole frac)

G = (mol/min) 1 (total mole flowrate)

——>

CFC Condenser

Temp(C) -90

Recovery Eff(%) = 71.25

VP(Psi) = 0.455

CFC 12

——>

yCFC 0.030952

yN2 0.969047

CFC Con (ppmm) 30952

Temp (C) -90

V = (mol/min) 0.928746

xCFC = 1

L = (mol/min) 0.071253

Solution Algorithm

1) Select CFC and input the number in cell E4

2) Select influent CFC concentration
and input into B19

3) Select condenser temperature and input into
cell G16 (this must be a multiple of 10 and > than FP)
ie. -100, 30, -20 etc.

4) Execute MACRO by hitting ALT M

5) The program will select the pertinent physical
and chemical properties from the CFC table and
use these in the calculations

6) Recovery calculations are based on the following model:

1) G = V + L	overall mass balance
2) GzN2 = VyN2	nitrogen balance
3) xCFC*PsatCFC = yCFC*Ptot	Raoult's/Dalton's Law
4) yN2 = yCFC - 1	mol fraction constraint

7) CFC Vapour Pressure is from Du Pont data and/or
extrapolation of Antoine Equations (for low temperature data)